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*Looking South Across
Big Fill*

HANDLING SLIDES in the American Canyon Cut-off

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THE so-called American Canyon Cut-off on California State Route 7 and U. S. 40 between the Carquinez Toll Bridge and Cordelia, on the State Highway between San Francisco and Sacramento, now being graded, is a change in the location of this important road, which will make a saving of six miles in distance and eliminate all grade crossings with railroads, there being five on the present route. The alignment and grades will also be greatly improved.

This grading contract, 10.3 miles in length, is especially noteworthy for the size of the cuts and fills. One cut 130 ft. deep and 2400 ft. long, has an estimated yardage of 520,500 cu. yd., which is nearly half of the estimated total of 1,166,000 cu. yd. of excavation on the job. Adjacent to this cut on the north is a fill 75 ft. high and 2500 ft. long, having an estimated volume of 605,600 cu. yd. This yardage will come partly from the "Big Cut" above mentioned and partly from another cut to the north with an estimated excavation of 217,300 cu. yd.

Method of Handling Slides.—In the May issue of *ROADS AND STREETS* this project was described and several suggestions were made as to possible methods of handling the large slides, which were developing adjacent to several of the cuts.

The statement was made that in none of the slides had there been any indication of water. Shortly after the article was written our test borings encountered consid-

erable water in the large slide at Station 400+, and hoping to avoid moving the entire slide we decided to start cutting a trench with power shovel from about road grade and at right angles thereto, expecting that we would drain this water and stop the movement of this slide. However, the slide moved in from all sides towards the shovel so rapidly and was so broken up that no water was reached. We did, however, stop the movement of the slide into the roadway section and were probably saved moving considerable material.



Sta. 400. Slide, Looking Southerly



Removing Slide, East Side of Big Cut

In the "Big Cut," as the depth has increased, the soil has continued to crack and move in toward the roadbed in spite of our attempts to relieve the load above the sliding plane by working it off with scrapers and bulldozers. This condition is much worse on the east side than on the west, and we are now working a power shovel along the top of what appears to be a fairly stable formation and are planning to remove enough of the broken slide material to prevent further movement into the roadway section.

This additional material is being used to raise the "Big Fill," reducing the grades and also to widen the roadbed to take care of future additional lanes of pavement.

In order to insure a solid fill throughout, the material for widening is being dumped by trucks over the side, pushed down by bulldozers, and is then spread out along the bottom of the fill by bulldozer and compacted by sheepfoot tampers.

At another slide in the vicinity of Station 392, where the movement has been slight to date, we plan to remove the loose top of the slide with scrapers and bulldozers, down to solid material. This surplus material will also go into the "Big Fill."

The work has been progressing at a good rate with the same equipment operating as before, namely, four power shovels and three large scrapers, pulled by tractors.

The original estimated excavation was for 1,166,000 cu. yd. Since October, 1933, it is estimated that a total of 1,129,000 cu. yd. of excavation has been removed and placed in the fills, a considerable amount being from the slides.

The present contract calls for grading and drainage structures, and should be completed early this fall.

The grade is being built from $\frac{1}{2}$ to 2 ft. low, as the soil is largely of a clay and adobe material with a high shrinkage, it being our intention, in the next contract, to bring the roadbed to grade with selected material of low shrinkage upon which pavement may safely be placed.

The Cordelia Subway.—The subway and approaches under the only railroad contacted, located at the Cordelia end of the job, being done under separate contract, is progressing satisfactorily. This subway, a concrete and steel structure, which is to support a single track over the highway, will have a 40 ft. clear roadway with space for a 3-ft. sidewalk on either side.

The track is supported by two steel girders, 100 ft. 11 in. over all with a span of 96 ft. 3 in. between supports. They have a maximum depth at the ends of 9 ft. 9 $\frac{3}{4}$ in. and the bottom center 83 ft. 5 in., is built on the arc of a curve, making the girder 7 ft. 4 $\frac{1}{2}$ in. deep at the center. The abutments and wingwalls are of reinforced concrete and rest on pile foundations.

The entire job should be finished this fall. It is hoped that this important project will be paved and ready for traffic next year. The contracting firm handling this project is Granfield, Farrar and Carlin of San Francisco, their field superintendent is John Carlin. The State is represented on the job by A. N. Lund. Earl Lee Kelly is Director of Public Works and C. H. Purcell is State Highway Engineer. The project is in District X, of which R. E. Pierce is District Engineer.

The contracting firm handling the subway and approaches is F. O. Bohnett, of Campbell, Calif. This contract is being handled by the Bridge Department of the Division of Highways, F. W. Panhorst (Acting) Bridge Engineer. R. H. Twaddle is Resident Engineer on the job.

Sta. 400. Removing Slide





BULLDOZERS AND LARGE SCRAPERS IN HIGHWAY GRADING

THE use of large tractor-powered bulldozers as actual excavating units and the use of large capacity scrapers are comparatively recent innovations in highway grading. From time to time these types of equipment have been found in use on jobs on which production studies were being conducted by the U. S. Bureau of Public Roads, and in the May issue of *Public Roads*, Andrew P. Anderson, Highway Engineer of the Bureau summarizes and reviews briefly the data thus accumulated. The matter following is reprinted from his report.

The bulldozer has long been standard equipment on the dump or fill, but its use in the cut as a combined excavating and hauling unit has, until recently, been very limited. All available data, however, indicate that the bulldozer and the modified type frequently known as the "trail builder" are well adapted to moving common excavation where the hauls are comparatively short and down rather steep grades and the materials are, or can be made, loose enough to permit the rapid accumulation of a load. If the material is at all hard or solid, it should be loosened with a rooter or a scarifier, or by blasting. The bulldozer is entirely satisfactory only where the ground is loose enough to permit a load to be picked up within a length of 25 to 40 ft. with the tractor moving at a speed of 2.0 to 2.5 ft. per second. If the material is too hard or tight to permit a full load to be picked up in from 10 to 20 seconds, it should be loosened with a rooter by scarifying or by blasting.

Bulldozers Used in Conjunction with Power Shovel.—The tractor-powered bulldozer has thus far found its widest use as an excavating unit in conjunction with the power shovel when operating in rather rough, broken country with a deep mantle of soil or deeply weathered and decomposed rocks and shales. The bulldozer has certain characteristics which appear to limit its profitable operation as an excavating implement to jobs having these general features. It is most effective in moving material down steep slopes. As the grade decreases the efficiency decreases very rapidly, and on an ascending grade the efficiency of transportation is very low.

Proper material is essential. The material must be naturally loose or at least sufficiently friable to permit rapid and direct accumulation after loosening. Hard

rocks and very hard shales can rarely be shattered sufficiently for movement with a bulldozer.

A relatively short haul is the third requirement. The tendency of the materials to spill around the ends of the bulldozer blade usually makes long movements unprofitable. Unless the grade is very steep a large load at the start will soon dwindle to a small one. Where a large yardage is moved along one path a trough or trench is formed by spillage around the ends of the blade and soon becomes sufficient to reduce further spillage. This advantage of path movement on long hauls should be utilized as much as possible. Sometimes the spillage around the ends of the bulldozer blade can be reduced by working two bulldozers abreast, with their blades only a few inches apart. Observations on a job where this was tried indicated that the yardage moved per trip by the two tractors was increased nearly 20 per cent over that moved when working independently.

The bulldozer is particularly useful in conjunction with the power shovel. On steep ground the pioneer road work necessary for the shovel to reach the first lift of a deep cut can frequently be greatly reduced and sometimes entirely eliminated by having the bulldozer build up both an approach for the shovel and a hauling road for the trucks or wagons. Often a cut which would normally be made in two or three lifts may be reduced in this way by one lift and better hauling roads provided because of the adaptability of the bulldozer to the conditions. With the bulldozer this can generally be done with the movement of only pay materials, whereas the older method frequently requires the movement of considerable quantities of nonpay materials in the construction of approach roads in zigzags up the steep slopes.

The bulldozer has been found effective in sidehill work. Work is usually begun along the upper line of slope stakes and the material moved ahead and to the side as the conditions may require. So long as the material is loose or can be loosened and the haul distance is short enough to maintain a rather steep grade along which to move the material, good production rates can be maintained.

Operating Speed for Bulldozers.—The best operating speed at which to haul the loads is still largely a matter

of opinion. The general practice is to work at about the maximum speed possible without obviously straining the power unit. This practice may be entirely correct for many or possibly most cases. It was noted during recent job studies that in moving loose, noncohesive material down steep grades the amount of material which would push or flow in front of the blade was much larger at a speed of 2 ft. per second or less than for a speed of 3.5 ft. per second. There appears to be some optimum speed which will yield the greatest production, at least when moving loose, noncohesive materials down steep grades. However, no definite data are available as to what this most productive speed is or how it may vary with different materials and on different slopes.

Opening a cut with the bulldozer in ground as described above is comparatively simple, although on very steep ground considerable skill and ingenuity are required in maneuvering the bulldozer in its climb to the very top of the cut. Once this point has been reached the bulldozer begins to dig along the highest point of the upper slope line. The excavated material is pushed ahead toward the fill. If the ground slope is steeper than the tractor can readily climb in reverse, the material is simply pushed clear of the immediate excavation and allowed to accumulate along the line of the hauling road until a runway is provided with flat enough grade to permit the bulldozer to return readily in reverse after delivery of its loads to the fill. If the ground slope is already flat enough for the tractor to return fairly easily, every load is carried to the fill. In both cases the slope of the hauling road for the bulldozer is kept as steep as possible because, within limits, the steeper the grade the larger the load which can be carried to the fill.

As the work progresses the runway is widened to finally include the full width of the cut. In a wide cut three or four bulldozers can sometimes be operated without interference, and even more if the haul is in both directions. If the material becomes too hard for easy loading, a heavy scarifier or roofer drawn by a powerful tractor may be used to loosen it. If the ground becomes still harder, blasting should be resorted to. The harder rocks and shale, however, can seldom be reduced sufficiently to make the use of the bulldozer profitable. When rock or ground of this nature is reached further work is left to the power shovel.

The steeper the grade the larger the load which can be carried to the fill and the longer the haul on which the bulldozer can be used profitably. The only limit to the grade is the ability of the tractor to climb on the return. A large crawler tractor in good condition and equipped with a 10-ft. standard bulldozer has been observed to climb a grade as steep as 50 per cent.

Operating Characteristics of Tractor-Powered Bulldozers.—Field observations indicate that the average load which can be carried from cut to fill under ordinary field conditions varies with the length and shape of the blade, the grade along which the load is moved, and the character of the material. The observations are confirmed to some extent by the data of Table I. During recent studies of the use of four bulldozers in moving considerable yardages it was found that loads frequently fluctuated as much as 100 per cent. For a certain bulldozer the smallest loads would be about 2 cu. yd., and the largest loads would be about 4 cu. yd.

Recent improvements in control which permit independent vertical movements of either end of the bulldozer and also lateral movement have considerably improved the utility. It is easier to keep the entire cut in proper condition for easy operation, and to shape the slopes at the proper angle. These features are particularly valuable in sidehill work.

TABLE I.—OPERATION CHARACTERISTICS OF TRACTOR-POWERED BULLDOZERS.

	Bulldozer No.			
	1	2	3	4
Number of trips timed.....	3,731	511	860	560
Cubic yards placed in fill.....	11,741	1,655	1,822	1,352
Production rate, cu. yds. per hour	68.4	57.0	35.2	44.1
Pay yardage per load, cu. yds..	3.15	3.24	2.28	2.41
Loading distance, feet	30.0	40.0	28.0	39.0
Loading speed, ft. per second...	2.4	2.4	1.4	2.7
Haul distance, feet	168	216	309	232
Hauling speed, ft. per second..	3.7	3.2	3.2	3.1
Return distance, feet	200	260	340	275
Return speed, ft. per second...	2.3	2.5	4.7	2.5
Average grade, per cent	—26	—17	—11	—20
Operating cycle:				
Load, seconds	12.6	16.6	20.6	14.3
Reverse or turn at dump, seconds	1.9	2.0	2.6	2.5
Turn or shift at cut, seconds..	2.0	2.4	2.8	2.4
Minor time losses, percentage of working time	12.6	14.5	18.0	16.2
Size of blade, feet	4 by 10	3 by 11.5	4 by 10	4 by 10
Rated horsepower of tractor...	65	65	60	60

Large Tractor-Drawn Scrapers Studied.—Large tractor-drawn scrapers have been studied on a few grading jobs having large quantities of short-haul common excavation. These scrapers ranged in rated capacity from 3 to 8 cubic yards of loose material and were of six different makes. This number of different makes indicates that this type of equipment is far from standardized. However, those observed may be divided into two distinct classes: Those which carry the load pan or scoop clear of the road, and those which drag the load pan or cutting blade so as to transport a part or all of the load by pushing it ahead of the pan or cutting blade.

Some of those which lift the pan have definite provisions for preventing or reducing spillage while the load is being hauled to the dump. These provisions vary from substantial self-closing gates to simply tilting the load pan to such an angle that the tendency for the material to spill out is greatly reduced. In the other class, the pan is raised very little for the haul and spillage is prevented or at least neutralized by accumulating and dragging material in front of the pan.

TABLE II.—OPERATING CHARACTERISTICS OF LARGE SCRAPERS.

	Scraper No.			
	1	2	3	4
Rated capacity, cu. yds.....	3	6	8	4
Condition of equipment	Good	Very good	Very good	Very good
Number of round trips timed	212	269	132	145
Loading distance, ft.....	75	116	144	80
Loading speed, ft. per second	2.3	1.8	2.0	2.1
Hauling distance, ft.....	180	327	290	210
Hauling speed, ft. per second.....	2.9	3.5	2.8	3.0
Return distance, ft.	254	405	449	280
Return speed, ft. per second.....	3.2	3.8	3.8	3.7
Dumping time, seconds	10.4	.....	.....	.....
Turning time, seconds	18.0	22.0	20.0	24.0
Size of load carried to dump, percentage of apparent full load...	95.0	75.0	50.0	90.0
Average pay yardage in percentage of rated load capacity	57.0	45.0	35.0	54.0
	Scraper No.			
	5	6	7	8
Rated capacity, cu. yds.	5	4	4	5
Condition of equipment	Very good	Fair	Good	Fair
Number of round trips timed	54	56	3,200	963
Loading distance, ft.	86	92	100	38
Loading speed, ft. per second.....	2.0	1.8	2.0	2.3
Hauling distance, ft.	372	1,400	300	237
Hauling speed, ft. per second.....	3.2	3.0	2.5	3.3
Return distance, ft.	450	1,450	400	275
Return speed, ft. per second.....	3.8	4.7	5.5	2.7
Dumping time, seconds	46.0	34.0	11.0	10.4
Turning time, seconds	27.0	22.0	20.0	.....
Size of load carried to dump, percentage of apparent full load...	61.0	75.0	90.0	.....
Average pay yardage in percentage of rated load capacity	37.0	45.0	53.0	44.0

Adjusting the pan so as to drag material produced a considerable effect on the hauling speed. When the scraper was hauled with the load pan clear of the ground the hauling speed was generally 30 to 50 per cent higher

than when the pan dragged sufficiently to retain a full load. The effect of reduced speed, however, seemed fully compensated by the increased load. With the pan hoisted entirely clear of the roadway, the loss from spillage on steep or rough down grades was as much as one half of the original load when the soil was dry and noncohesive. Considerable difficulty was sometimes experienced in dumping the gate type of scraper when working in sticky or plastic materials.

Results of observations on four jobs using six different types of scrapers are shown in Table II. Scrapers 1, 2, 3, 4, and 5 were all on one job and operated under fairly similar conditions. Job 7 was observed only in the winter when the materials were wet, sticky, and difficult to handle. Scrapers 1 and 7 and 5 and 6

were of the same make and type but were observed on different jobs and under different conditions.

AUTOMATIC TRAFFIC COUNTER.—Science Service, Washington, D. C., reports a device now in use at the Massachusetts Institute of Technology which records each automobile entering the grounds. Two light beams several feet apart are focused on two photo-sensitive cells and a counting relay registers every time the two beams are interrupted by a large object such as an automobile. Pedestrians interrupt but one beam at a time and hence are not counted. The speed of the vehicle may be measured by noting the small time interval between the interruption of the two light beams.

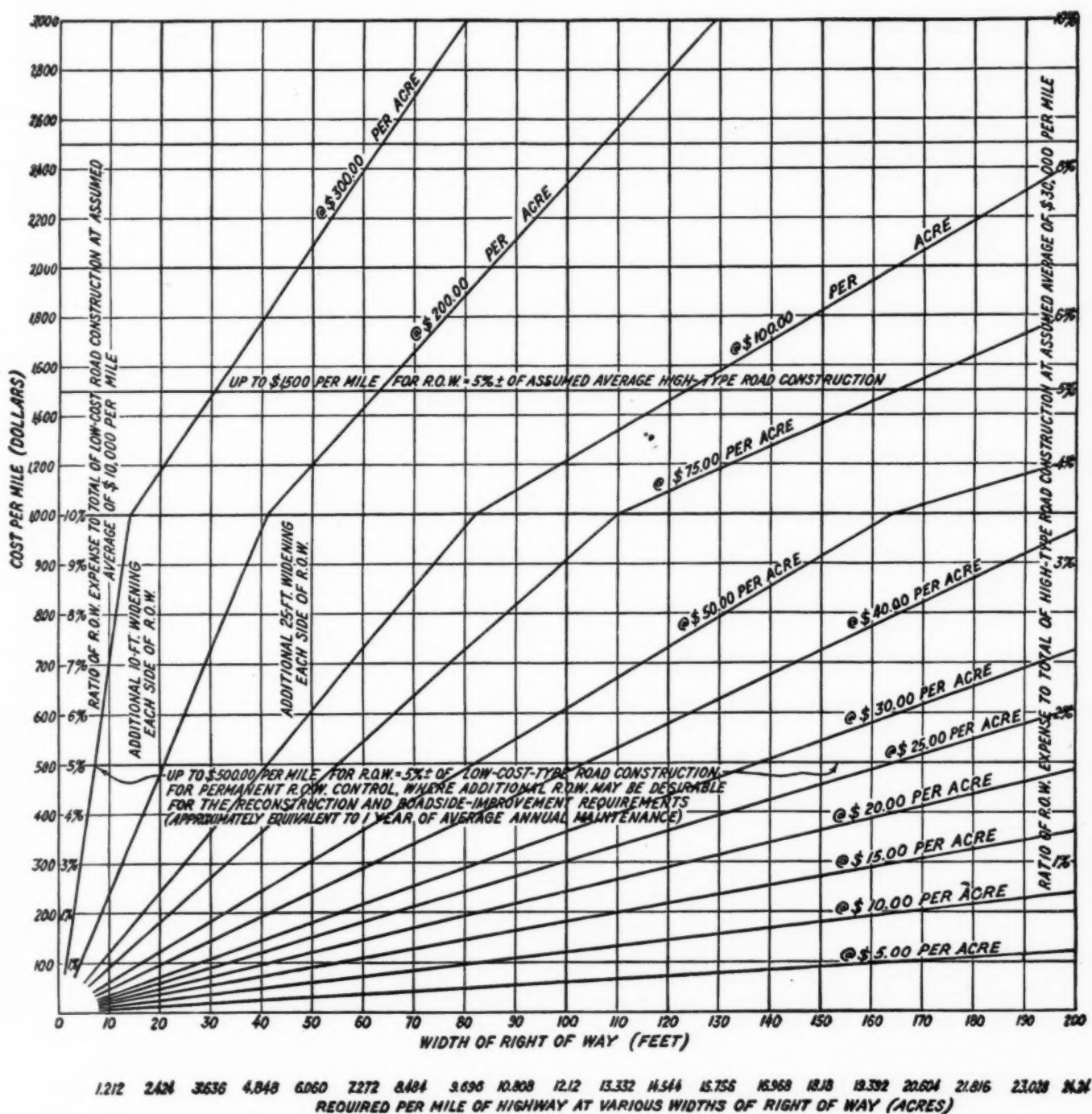
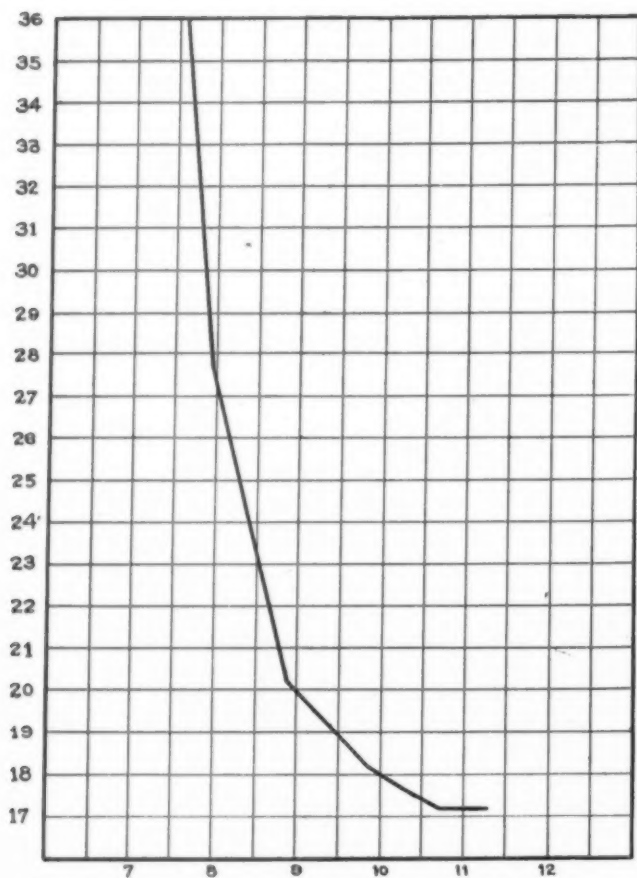


Chart for Determining Cost per Mile of Right-of-Way of Various Widths and Costs per Acre and Relation between Cost of Right-of-Way and Cost of Construction of Average Low-Type and High-Type Surfaces. (From *ROADSIDE IMPROVEMENT*, a Recent Publication of the U. S. Department of Agriculture.)



Compacting Followed Promptly
Pouring of the Grout

CEMENT BOUND MACADAM Placed On A 13% Grade



Cone Flow = W/C Ratio Curve Cumberland River Sand

A RECENT paving job with cement bound macadam of a private driveway on the estate of Joe Gibson, Nashville, Tenn., is of particular interest because of its important contribution to methods of laying cement bound macadam on steep grades. A section of this driveway was on a 13 per cent grade, yet cement bound macadam was placed without difficulty.

The cement bound macadam driveway replaced a surface treated drive. Rock from the old driveway was salvaged and used to stabilize the subgrade for the new cement bound macadam pavement.

After the curb and gutter was completed, approximately 1 in. of the salvaged crushed limestone was spread over the subgrade and rolled 8 or 10 times with a 3-wheel, 10-ton roller.

Gravel Used as Coarse Aggregate.—Gravel coarse aggregate, size $1\frac{1}{4}$ to $2\frac{1}{2}$ in., was then deposited in a layer 5-in. in depth. Dump trucks which delivered the coarse aggregate to the job were backed up the grade. Truck bodies were elevated for dumping, tail gates were slightly opened and trucks allowed to slowly roll down grade depositing the coarse aggregate in a fairly uniform layer. Stone rakes were used to evenly distribute the coarse aggregate. Sub-grade treatment had been so well done that trucks left no imprint of wheels. As a result, there was no dirt or loose material to impede penetration of grout at the bottom of the slab.

A 1:2 grout was used, based on dry, rodded volumes, although materials were measured by weight. Cumberland River sand was used. As delivered the sand weighed 78 lb. per cu. ft. When dry rodded it weighed



Grout Was Mixed at Top of Slope

96 lb. per cu. ft. It had a moisture content of 4 per cent. The sieve analysis was:

Sieve Size	Grams Coarser	Per Cent Coarser
No. 8	1.9	1.3
No. 14	18.0	13.5
No. 28	32.0	35.2
No. 48	66.8	80.6
No. 100	28.0	99.7
Passing No. 100.....	.4	...
Fineness modulus .....	...	230.3

The sand was a rather fine 0-8 classification, barely escaping the 0-14. A total of 8.9 gal. of water were used per sack of cement.

Grouting Operations Were Carried Down Grade.—Grout was transferred from the mixed to the coarse aggregate by wheelbarrows and deposited on a splash board to prevent disturbance of the particles of coarse aggregate. There was a tendency for the grout to push the coarse aggregate down-grade and extreme care was used in the grouting operation. Excess grout and aggregate which tended to roll down-grade were pushed up-hill with push brooms. Test holes indicated proper penetration of grout and also showed no tendency for the grout to flow an excessive distance ahead of the grouting.

Compacting Done With Hand Tamp.—The grouted coarse aggregate was compacted with a hand tamp. This tamp was made of a standard 6 in. I-beam, 12 ft. long equipped with plow handles. Long handle wooden floats were used for floating the excess grout brought to the

surface. After water sheen had disappeared the entire surface was dragged with a wet burlap. Brooming was omitted as a sufficiently rough surface was obtained to get good traction and it was thought that too rough a surface would not be desirable for a residence driveway.

The slab was cured by frequently wetting it down with a hose.

Expansion joints placed at intervals of approximately 40 ft. were of $\frac{3}{4}$ x 6 in. untreated pine lumber left in place. After the slab was completed, joints were chiseled out to a depth of $\frac{1}{2}$ in. and filled with hot asphalt.

The excellent riding surface obtained was most favorably commented on by visiting state highway engineers and paving contractors.

Extreme care used in sub-grade preparation and in grouting operations on that portion of drive on 13 per cent grade resulted in only 1 sack of cement being used in excess of the amount theoretically required.

It is thought that the use of gravel as the coarse aggregate subjected the construction procedure to the most severe test. Crushed limestone rock would have tended to key and could have been compacted prior to grouting. The lack of keying action between the particles of gravel required greater care in grouting operations. The day's production, however, despite the greater care used, compared favorably with work on comparatively level grades. Riding surface and general appearance differed in no way with the cement bound macadam on the balance of the driveway.

W. L. Hailey & Co., Nashville, Tenn., was the contractor.



Compacting with Template Made of Steel I-Beam. There Was No Objectionable Flow of Grout While Compacting



Finishing with Wood Floats Prior to Covering with Wet Burlap

RIGID FRAME BRIDGES

In Grade Crossing Elimination

By A. J. BOASE

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A CLEAR conception of the one-span rigid frame may be obtained by visualizing a deck supported on two abutments. Three typical structures suggest themselves, namely: a deck with one anchored support and one sliding support, a deck with two fixed supports, and a structure with rigid connections between deck and abutments. The one-span rigid frame bridge is of the latter type.

These represent three fundamental types of one-span bridges. The first has been used extensively during the past 50 years. It is used in the bridges employing concrete T-beams or rolled I-beams in the decks. The abutments in this case are designed as cantilever retaining walls. The maximum bending moments in this type of bridge occur at the middle of the deck and at the bottom of the abutments.

The bending moments in the abutments in the second type are considerably smaller than in those in the first, and the volume of abutment material and footing excavation is accordingly reduced. This type of structure deserves more attention than has been given to it in the past. It serves a useful purpose under various field conditions and is more economical than the ordinary simple span.

The rigid frame has an economic moment distribution in the abutments similar to that in the second. In addition to this, the distribution of the bending moment in the deck is far more advantageous than in the other two types. For example, the bending moment in the simply supported deck is all positive, and the maximum moment which occurs at the crown governs the depth of the deck which is made uniform from abutment to abutment. In the rigid frame, however, due to end constraint, there is a more equal distribution of the moments throughout the deck. The average bending moment in the deck is less, and that in its middle portion is materially reduced, thereby effecting a saving in thickness.

In the rigid frame, the greatest moments and the deepest sections are at the corners. Small moments and thin sections occur at the lower portion of the abutments and at the middle of the deck. It is seen that the distribution of bending moment and material in the rigid frame is somewhat different from that in the conventional type of structure. This "reversal of form" is one of the fundamental advantages of the rigid frame.

Utilization of Elastic Properties of the Structure.—

Consider a deck simply supported on two abutments and also a deck rigidly connected to the top of the abutments. Assume that a load, F , is applied at the center of both decks, and the deflections caused by the loads, F , are d_1 and d_2 .

The external work performed during the gradual application of the load is $\frac{1}{2} Fd_1$ and $\frac{1}{2} Fd_2$ respectively. These expressions for the external work must equal the internal work or resilient energy stored in the elastic frame. In the case of the simply supported deck, all of the external work is stored as resilient energy in the deck; but in the rigid frame, resilient energy is also stored in the abutments. In other words, in the rigid frame the entire structure is put to work. A little consideration will show that the bending moment required to balance the external loads are smaller in the rigid frame than in the conventional bridge type.

We may therefore conclude that putting the entire structure to work tends to reduced the bending moments, and means that sections can be reduced. Therefore, the full utilization of the elastic properties of the entire frame results in a distinct saving in material in the rigid frame type of structure.

Estimating the Frame Dimensions.—The moments and shears in the simply supported deck are functions of the deck span and loading only. In the rigid frame, however, the moments are also influenced by the proportions of the abutments. If, for example, the abutments are relatively high and thin, d_2 may be nearly equal to d_1 and the points of inflection in the rigid frame deck are near the corners of the frame, consequently the bending moments in the two decks are nearly equal. When the abutments are relatively shorter and thicker, the value of d_2 decreases, the points of inflection move toward the mid-point of the deck, and the moments become smaller at the middle and larger at the corners of the frame. It is obvious that the design of a rigid frame must be based on the relative proportions of the entire frame.

Design problems are further complicated by the fact that the relative proportions of the frame must be known before a bending moment analysis can be made. Much time may be saved in the analysis by making the preliminary frame layout conform to empirical rules which have been derived from similar structures that have already been designed. Rules which have been found to

give satisfactory preliminary proportions for frames intended to support heavy highway loadings are as follows:

(a) Lay out the top of the deck ABA' according to the roadway requirements.

(b) Determine the clear span, L .

(c) Lay out BC equal to about $L/35$. This value may be reduced to $L/40$ when the frame is founded on a practically unyielding foundation; it should be increased where the footings rest on highly compressible soils.

(d) Lay out AD and DE equal to about $L/15$.

(e) Draw the soffit curve DCD' .

(f) Determine the elevation of F and G from the clearance requirements and foundation conditions.

(g) Lay out FG equal to about 1 ft. 6 in. for 30-ft. spans, about 2 ft. 6 in. for 60-ft. spans, and about 3 ft. 4 in. for 90-ft. spans.

(h) Connect E and F with a straight line.

The essential frame dimensions have now been determined and the designer can proceed to the detailed analysis.

Cross-sections through rigid frames may be either rectangular or T-shaped. For larger spans and under certain conditions, it may be economical to use a ribbed deck and perhaps also ribbed abutments.

The rigid frame is applicable to bridge layouts which require any arbitrary number of spans. For example, a rigid frame bridge with three spans and open end bents is often economical and suitable for grade separations, especially when these are built in rural regions.

Characteristic Features of the Rigid Frame Bridge.—A comparison of the conventional T-beam girder bridge and a rigid frame bridge will indicate the differences in the two types of structures. Troublesome details at the top of the abutments are eliminated in the rigid frame structure. The rigid frame requires no sliding plates and no rollers or rockers; it has one expansion joint which is of simple design at each end. No movement of the top of the abutment toward the span opening is possible in the rigid frame; neither is there any possibility of the deck creeping on the bridge seat. These simplifications carry great weight with engineers in charge of construction and maintenance of highway bridges. The rigid frame bridge is simple to construct and easy to maintain.

An outstanding feature of the rigid frame bridge is the shallow depth required for the deck. A comparison between a flat deck arch and a rigid frame type shows that the roadway can be lowered considerably by the use of a rigid frame structure. The average thickness of rigid frame decks can often be made as small as one-twenty-fifth of the span for ordinary highway loadings. Usual simple supported deck construction requires a depth for deck that varies from 50 to 100 per cent more than this.

The deck of a rigid frame structure is not only shallow but the deck material is also distributed to better advantage than in other types of structures. The minimum thickness of the deck is over the part of the roadway on the underpass where the greatest clearance is required. The deeper deck sections are near the abutments and over the sidewalks or the shoulders where clearance requirements may be reduced. From a purely utilitarian standpoint it is seen that the shape of the deck in a rigid frame bridge is adapted to conditions at grade separations.

Adaptability of the Rigid Frame Bridge to Grade Crossing Eliminations.—When the crossing at grade of two intersecting roads is to be eliminated, it is necessary either to raise one road by building approach ramps on fill or to lower the other road by building approach ramps in cuts. It often becomes necessary, especially where the land value is high, to build a system of retaining

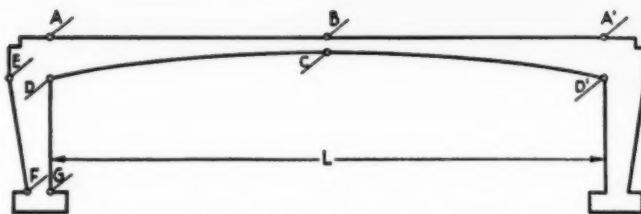


Diagram for Proportioning Rigid Frame Span

walls to hold the earth. Under such circumstances, each additional inch of depth required for the construction of the deck will increase the cost of the approaches.

Comparative estimates of first cost for four types of grade separation structures were prepared by the Westchester County Park Commission, N. Y. The cost of the approaches was about 60 per cent of the total first cost, or about 50 per cent more than the cost of the overhead structure itself. The estimates also showed that the cost of the approaches vary with the type of structure chosen; in this instance the highest approach cost was about 40 per cent more than the lowest approach cost. It was also found that the most economical overhead structure was the one which had the most economical approaches. The solid rigid frame bridge which was about 20 per cent lower than the nearest structure was found to be most economical. It is generally true in grade separation structures that the most economical structure has the shallowest deck.

The elimination of grade crossings is prompted by a demand for safety. It is essential that the structure interfere as little as possible with the flow of traffic. The choice of structure from the viewpoint of traffic safety is generally dependent on the judgment of the bridge engineer, whose function is to decide how much money can justifiably be spent for additional safety measures. This problem is rarely susceptible to an exact evaluation.

It is often desirable to omit intermediate piers in grade separation structures and still it is essential that the thickness of the deck should be kept as shallow as possible. The rigid frame bridge fulfills both of these requirements in that it can span longer openings with less construction depth than any other deck type of bridge. Compared with the simple supported deck types, the greatly reduced positive bending moments in the rigid frame deck make it possible to extend its free unobstructed span length beyond the span lengths now used in conventional designs.

Variations of Rigid Frame Principle.—Many valuable variations of the rigid frame principle have been used in recent years in order to increase the span of the deck and still maintain a minimum depth of construction. One of the most promising developments is the extension of the deck structure as cantilevers beyond the end piers. Suitable counterweights may be added at the extreme ends of the cantilevers in order to reduce the positive bending moments at the middle of the deck. This is the engineering principle according to which the Herval Bridge, Brazil, was designed and constructed and made possible the building of the longest concrete girder span to date. This span is 224 ft. and the girder has a depth at mid-span of only 5 ft. 7 in., or $1/40$ of the span length. The application of the rigid frame principle permits the extension of concrete girder spans far beyond those which are generally used today. Under the right circumstances these long spans are structurally feasible and economically justifiable.

For the spans ordinarily encountered in grade separations, the rigid frame makes these longer spans both practicable and economical and does not require the use of intermediate piers.

A rigid frame bridge designed for Cooper's E-60 loading has recently been built at Vaudreuil, Canada. Considering this heavy loading, the clear span of 72 ft. 6 in. is impressive; however, the thickness of the deck is only 3 ft. 9 in. at midspan.

The rigid frame is a deck structure; that is, the entire supporting structure lies below the top of the deck. A deck structure involves two safety elements, namely, there are no projecting structural parts and therefore the least possibility of collision with and damage to passing vehicles. The concealment of the structure is also of vital importance to its own safety, because some bridges have collapsed after collision has weakened some structural part.

Deck structures are easily widened. This is of major importance in modern bridge building. A bridge which cannot be easily widened too often remains in place long after its inadequate roadway width has become a serious menace to the congested traffic passing over it.

Rigid Frame is Economical.—The cost of a bridge is made up of several items which can be compared most readily if they are all given in terms of the annual costs chargeable to the bridge.

The first item is the capital expenditure; that is, the contract price, C which is invested in the structure. With a prevailing interest rate of r , the annual cost of the invested capital becomes rC . It has been noted previously that low first cost of grade separations was obtained with the structure having the shallowest deck and that the use of the rigid frame for grade separations will mean the lowest first cost, C .

The structure must be maintained in its initial, or at least in serviceable condition. The charge for maintenance must be included in the annual cost. The maintenance work on the rigid frame itself usually includes the following items:

1. Repairing damaged handrailings.
2. Chipping out and waterproofing leaky construction joints.
3. Filling cracks on the surface of the deck.

The rigid frame structure has no bearings or expansion joints between the deck and the seats on the abutments; consequently, there is no maintenance of these bearings and joints. If a rigid frame type of construction is used in bridges which are continuous over two or more spans, the expansion joints over the intermediate piers are eliminated; so both first cost and maintenance cost are thereby reduced.

Despite the very best attention to maintenance and upkeep, any bridge will eventually require replacement. In other words, the capital in the bridge must be amortized. The cost, R , for amortization of capital which is often called the renewal charge is generally expressed by the formula.

$$R = \frac{r}{(1+r)^n - 1}$$

in which r = the interest rate.

n = the serviceable life of the structure in years.

The amortization charge, R , therefore can be reduced only by increasing n , the length of serviceable life.

The life of a bridge structure may be limited by one of four major causes:

1. Disintegration of the building material.
2. Inadequate roadway width.
3. Increased loading intensities.
4. New highway location.

It has been noted that the rigid frame has only a few vulnerable spots to maintain, consequently it may be expected to have an unusually long period of serviceable life. Furthermore, there will be no need of scrapping

a rigid frame bridge on account of inadequate roadway width, because the structure may be easily and economically widened. It is hazardous to attempt to predict future load intensities; however, it can be shown that rigid frames are less susceptible to overstressing due to live loads than the conventional bridge types because stresses in rigid frames due to superimposed loads are small in comparison with the total stresses.

It may be concluded from the foregoing comments that the rigid frame is equal to or even superior to conventional structures as far as disintegration, increase of width, and future increased loadings are concerned. On account of the longer serviceable life expectancy, the renewal charges which must be carried in the annual cost budget are comparatively low.

Insurance and operating charges do not apply to rigid frame structures. Salvage value enters into the economic study of temporary structures only.

Another item which may affect the annual cost is the change in abutting property values which are caused by the building of a bridge. This item should be considered, even if it cannot be definitely evaluated.

Conclusion.—The bridge engineer usually lets judgment decide in the choice between a structure that is merely utilitarian and one that is ornamental as well. Each type has its place. In grade separations, however, good appearance is considered a particularly valuable asset because grade separation structures are often built in densely populated regions, but regardless of the type of surroundings, these structures are always conspicuous from the underpassing roadway.

Popular choice in bridge architecture calls for curves and arches. The preference for arched structures appears to have a sound and logical basis. The masonry arch is one of the oldest bridge types and the stamp of age, tradition, and custom may have influenced public taste in this matter. The beam type of structure is of more recent development. It has been widely used in the last 50 years because it is adaptable to ordinary service requirements; however its profile does not satisfy the eye, which instinctively demands a clearance height that is greater at the middle of the span than at the supports.

The rigid frame provides a horizontal deck for the traffic as well as the arched ceiling. It opens a new and wide field for architectural expression to go hand in hand with engineering requirements of service and economy.

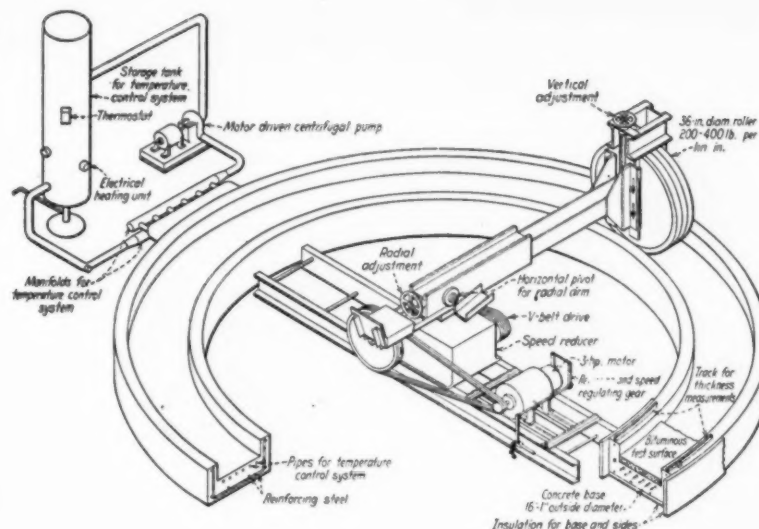
Acknowledgment.—The foregoing is a paper presented at the 1934 Highway Conference at the University of Colorado.

All Construction Must Be Registered

With official notification from Administrator Hugh S. Johnson of his approval of the financial budget of the Divisional Code Authority for General Contractors and the basis of contribution thereto by members of the industry, the Code Authority has undertaken an intensive nationwide checkup of all general contracts in excess of \$2,000, entered into on or after March 19—the effective date of the code—for the purpose of securing 100 per cent registration of this work.

While millions of dollars worth of work already has been voluntarily registered, and the 1/10th of 1 per cent assessment paid, failure to comply with these code provisions has not been treated as an NRA code violation prior to approval of the basis of contribution and the budget. From now on, however, the Divisional Code Authority has announced that a close check will be kept on all construction work to see that it is registered within fifteen days after being undertaken.

Fig. 1—Isometric View of Circular Testing Track



LABORATORY SERVICE TESTS FOR PAVEMENT MATERIALS

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THE testing engineer in the highway field frequently is confronted with the problem of deciding on proper specification limits for various types of highway materials. At times, he feels the need of some form of rapid service test which would permit him to correlate service results with routine laboratory tests. When new bituminous mixtures are proposed for use in highway construction, he would like to have some means for determining rapidly whether these mixtures have sufficient merit to warrant their inclusion in specifications. The determination of the relative value of different materials for particular purposes sometimes becomes an important problem and a rapid and convenient means for solving it would be valuable. Many other problems arise in the laboratory which can be solved only by correlation of laboratory tests with service behavior.

These considerations led in 1931 to the building of a laboratory apparatus by which road materials might be subjected to actual service conditions, or to conditions very closely approaching those in service, but having the advantage not existing in actual service tests, of temperature, moisture, traffic and subgrade control. In designing the apparatus, the problem of determining the relative stability of bituminous pavement mixtures seemed of principal importance, but the possibility of other uses was realized.

Description of the Circular Track Testing Apparatus.

—An isometric view of the apparatus is shown in Fig.

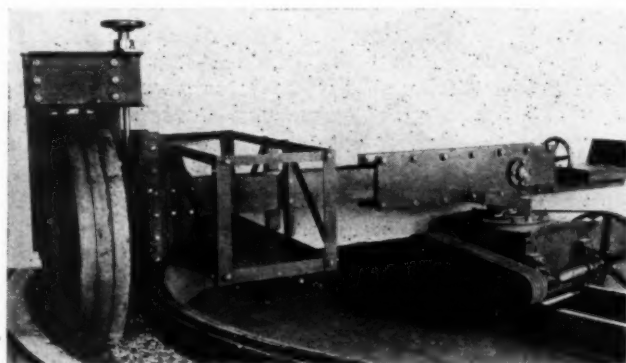


Fig. 2—Apparatus with Roller Assembly

1. The circular track is a concrete trough, 14 ft. in diameter at the center of the trough, heavily reinforced to prevent cracking due to wide variations in temperature and moisture. The trough is rectangular in cross-section, 18 in. wide and 6 in. deep. A 1-in. layer of insulating material under the track serves to prevent heat losses and to dampen vibrations. The sides are likewise covered with 1 in. of insulation.

To control the temperature of bituminous mixes, the track is provided with a heating system. Six pipes embedded in the concrete about $\frac{3}{4}$ in. below the bottom of the trough are connected to headers in such a manner that adjacent pipes carry flow in opposite directions to insure uniformity of temperature around the track. The headers are connected to a 30-gal. storage tank in which the circulating water is heated electrically and maintained at the desired temperature by thermostatic control. A centrifugal pump provides rapid circulation. The system is capable of maintaining the track, when covered, at approximately 140° F. using 5,200 watts of heating capacity. For curing bituminous mixes having volatile binders, the track is covered, except for two diametrically opposite openings. An electric fan, placed in one opening, forces air around the track in both directions and out at the other opening. The combination of heat with circulation of air permits rapid and uniform curing. By connection to a refrigerating machine of proper capacity and the provision of a suitable circulating medium, low temperatures or freezing conditions could be obtained. At quarter points, pipes through the outer wall to the bottom of the trough provide means for draining the track.

The roller, 36 in. in diameter and 6 in. wide, is built up of three cast-iron disks each of which is 2 in. (see Fig. 2). Each disk is free to revolve independently of the others in order to reduce the dragging effect due to

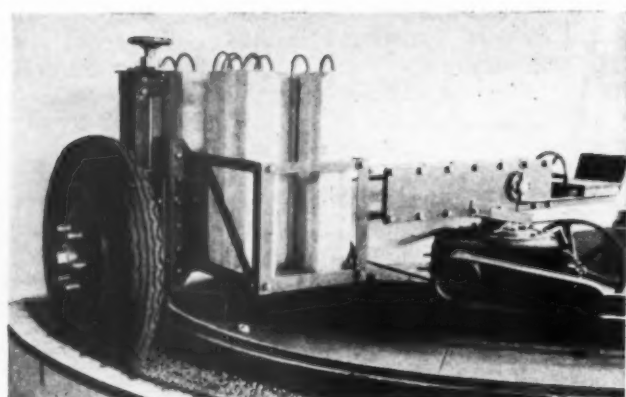


Fig. 3—Apparatus Equipped with Rubber-Tired Wheel

the travel in a comparatively small circle. The roller weighs approximately 200 lb. per in. of width. Driving is accomplished by the rotation of a radial arm about a vertical axis at the center of the track. The roller is attached to the outer end of the arm, the inner end of which is fixed to the vertical, slow-speed shaft of a worm gear speed reducer. Provision is made to allow some movement of the arm in a vertical plane to compensate for minor irregularities. To keep the roller face horizontal and the arm level on various thicknesses of pavement, the roller assembly is adjustable vertically.

The radial arm is built of two telescoping sections and is adjustable in length to allow the roller to be moved in or out to cover practically the full 18 in. of width in the track. This operation may be performed while the machine is running. Power is applied by a 3-hp. reversible, variable-speed motor through V-belts and a countershaft to the speed reducer. By changing the V-belt sheaves, major steps in speed are obtainable; intermediate speeds may be obtained by varying the motor speed. The present combination of V-belts permits a speed range from 0 to approximately 450 ft. per min., peripheral speed. A control lever mounted outside the track serves to vary the speed from full speed in one direction through zero to full speed in the other direction.

For simulating traffic conditions the roller assembly is removed as a unit and replaced with another unit carrying a rubber-tired wheel (see Fig. 3). A standard 7.00 by 20-in. pneumatic bus tire is used, inflated to 50 to 55 lb. per sq. in. It is loaded to its rated capacity of 1900 lb. by placing weights in a basket attached to the arm. To prevent raveling action due to the drag of the tire as it travels in a small circle, it has been found necessary to tilt the wheel about 6 deg. from the vertical (the top of the wheel toward the center of the track) and to provide about 2 deg. "toe in."

In the design of this apparatus careful consideration was given to the advisability of using more than one wheel. It was decided, however, that the extra complication involved and the increase in power requirements and weight would not warrant this. The method of driving was also thoroughly studied. Because of the structural complication and attendant difficulties of control, and because of the fact that, despite tractive effort, road surfaces tend to shove in the direction of traffic, it was decided that the more satisfactory solution would be the simpler method of driving from the center of the track with the driving mechanism stationary.

Throughout the construction of the machine, standard parts and materials have been used wherever possible. The motor and speed reducer are stock units, as are the V-belt drives. The arm and the heads carrying the roller

and wheel are built up of standard rolled shapes.

Auxiliary apparatus include a measuring device, or depth gage, for determining the thicknesses of the test sections, a spreader box, a screed, and a movable hoist for handling the roller and other heavy weights.

The depth gage is shown in Fig. 4. It consists essentially of a bridge spanning the trough and resting on strap iron rails mounted on the concrete curbing. Notched feet on the bridge fit over the rails and maintain its center line in a radial position. A slide moves radially across the bridge on guides in a horizontal plane and may be located by a scale attached to the bridge. A graduated vertical plunger is mounted on the slide. Thus, any point on the test surface may be located by the circumferential position of the bridge, the radial position of the slide, and the vertical distance as indicated by the plunger. The difference between the plunger reading previously taken on the concrete base and the reading on the test surface gives the actual thickness of the pavement. The rails on the curbing serve also to carry the spreader-box and the screed, thus facilitating accurate placing of material.

TABLE I.—GRADATION OF AGGREGATE USED IN ROLLING LOAD STABILITY TEST

Total Retained Per Cent	¾ to 2-in. Size	¾ to 1½-in. Size	½ to 1-in. Size	¼ to 1-in. Size	½ to 1½-in. Size	¼ to 1½-in. Size	¼ to ¾-in. Size
On 2-in. screen¹.....	2	..	..	..	2	..	..
On 1½-in. screen¹....	38	2	..	..	2	2	..
On 1-in. screen¹.....	74	63	2	2	47	38	..
On ¾-in. screen¹....	92	92	48	33	70	57	2
On ½-in. screen¹....	96	96	93	63	93	75	47
On ¼-in. screen¹....	100	100	100	93	100	93	93

¹Round openings.

The circular track has proved to be a versatile testing machine for the study of road materials. Several investigations are described, primarily to show how this apparatus has been used to study different highway problems and to indicate its possibilities.

Tests of the Inherent Stability of Aggregates.—The purpose of this investigation was to determine the inherent stability of aggregates under the action of a roller. The variables were depth of surface constructed and gradation of the aggregate. Only stone aggregate is included in the present report.

It was believed that the action of the roller in causing rutting of the surface of a loosely laid layer of aggregate should be an index of the inherent stability of the material; thus, if a material of one gradation ruts deeper than another under similar action of the roller, it seems reasonable to infer that this material would be less stable than the other. The seven gradations shown in Table I were each tested as follows:



Fig. 4—Depth Gage for Measuring Vertical Displacement

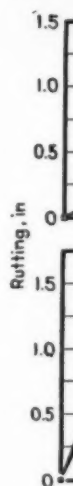


Fig. 5—

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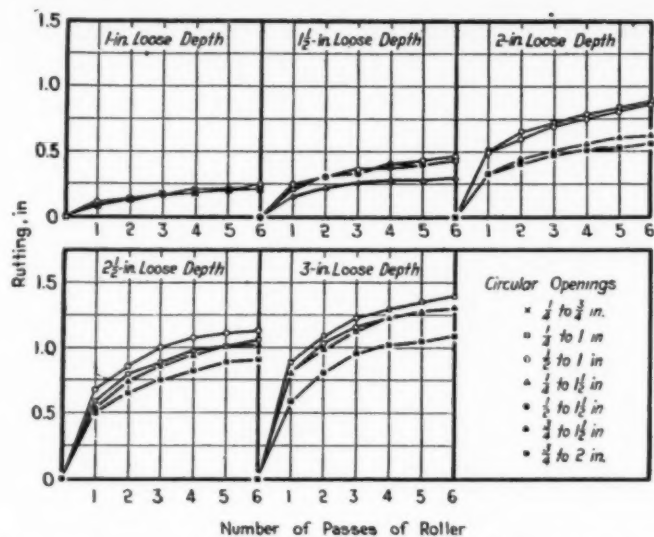


Fig. 5—Curves Showing Compacting Effect of Rolling Load on Macadam Layers

A uniform layer of stone was deposited on the concrete base over a length of about 11 ft., to form the test section. Initial thickness measurements were taken and the roller was run as follows: One passage over the inner 6-in. width, one passage over the outer 6-in. width, and one passage over the middle 6-in. width. The roller was then run over the middle 6-in. width for 5 additional passages and thickness measurements were taken after each passage.

In Fig. 5 are shown the amounts of rutting of the various layers after the designated number of passages of the roller. These tests seem to indicate that the gradation of the aggregate influences the stability of a layer of material subjected to rolling loads and that stability of a thin layer may be increased by using a gradation in which the maximum size of the aggregate approaches the compacted thickness.

Stone Screenings as a Blanket Layer Under Macadam.—An experiment was performed to investigate the efficiency of stone screenings as a blanket course under a macadam layer. Two subgrades were prepared, each covering half the circumference of the track. One was made with fine plaster sand and the other with plastic clay. The clay was mixed with water to a consistency such that, after compaction by means of a tamp, it could be walked upon without greater indentation than that about $\frac{1}{4}$ in. The sand was moistened and tamped, but was of such a nature that it could not be compacted appreciably. The clay contained 17.1 per cent of moisture and the sand 7.5 per cent. On each of these two subgrades three sections were laid as outlined below:

Section	Subgrade	Blanket Course Stone Screenings	1 1/2 to 2 1/2-in. Crushed Stone
No. 1.....	Clay	None	3 in. (loose)
No. 2.....	Clay	1 in. (loose)	3 in. (loose)
No. 3.....	Clay	2 in. (loose)	3 in. (loose)
No. 4.....	Plaster sand....	None	3 in. (loose)
No. 5.....	Plaster sand....	1 in. (loose)	3 in. (loose)
No. 6.....	Plaster sand....	2 in. (loose)	3 in. (loose)

The following table shows the gradations of the screenings and of the 1 1/2 to 2 1/2-in. stone:

Gradation of Screenings	Gradation of 1 1/2 to 2 1/2-in. Stone
Total retained, per cent:	Total retained, per cent:
On No. 4 sieve..... 0	On 2 1/2-in. screen..... 0
On No. 8 sieve..... 34	On 2-in. screen..... 59
On No. 16 sieve..... 60	On 1 1/2-in. screen..... 100
On No. 30 sieve..... 75	
On No. 50 sieve..... 84	
On No. 100 sieve..... 90	

The layers of screenings were placed loosely without any compaction and the stone layer was placed either immediately upon the subgrade or upon the loosely placed screenings to a loose thickness of 3 in. The roller was then run at a speed of approximately 3 miles per hr. in the same direction continuously around the track. The position of the roller was shifted laterally, about one inch for each round-trip. Approximately 60 passages of the roller were made over the track, during which time the roller was moved from the inside to the outside of the track and back again three times, making six complete lateral passages over each section. The effect of this action on the several sections is best seen in the accompanying Figs. 6 to 8.

In Fig. 6 is shown a surface view of the sand subgrade section containing 2 in. of screenings. The other two sand sections behaved in about the same manner as this one. The screenings layer was not effective in preventing the sand from working its way up into the stone.

In Fig. 7 is shown a cross-sectional view of the road surface having 1 in. of screenings on a clay subgrade. It will be noted that there is no upward penetration of the clay into the stone.

In Fig. 8 is shown a cross-sectional view of the section in which the stone is laid directly on the clay subgrade. Note how the stone has been pushed almost completely through the 3-in. layer of clay and how the clay has penetrated upward through the voids in the stone.

In conclusion, it would seem that when a macadam road is built on a clay subgrade, it would be a wise precaution to use a blanket course of screenings of 1 to 2 in. in thickness before laying the coarse stone. When the subgrade is composed of extremely finely divided clean sand, such as used in these tests, the screenings may not be efficacious.

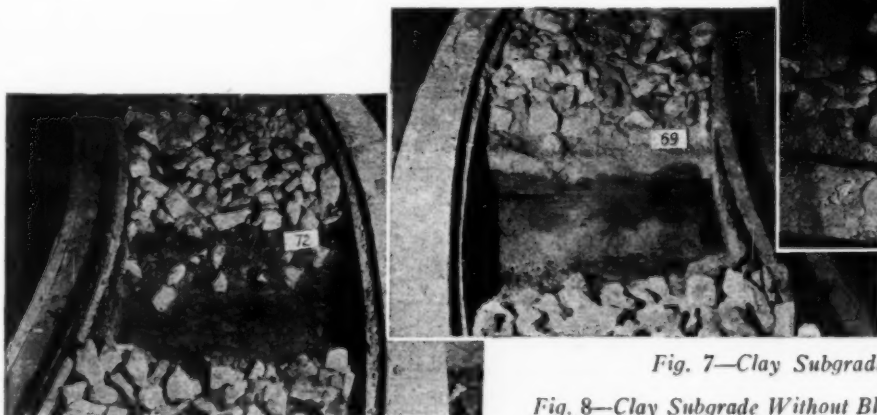


Fig. 7—Clay Subgrade with 1 in. of Stone Screenings



Fig. 6—Sand Subgrade with 2 in. of Stone Screenings

Fig. 8—Clay Subgrade Without Blanket Layer of Screenings

Study of Effect of Percentage of Bitumen and Characteristics of Aggregates on Stability of Road-Mix Surfaces.—An investigation has been conducted in an attempt to show the effect of bitumen content on the stability of open type, road-mix pavements. A preliminary study of the suitable amount of bitumen to use for the crushed stone aggregate gave 3 per cent. The stone used had a bulk specific gravity of 2.72 and a percentage of wear of 3.3. The gradation for each of the sections was the same: namely, $1\frac{1}{2}$ to $\frac{1}{4}$ in., "straight line" gradation. The cut-back asphalt, which was used, was purchased to conform with the following specifications: Flash point (Tag Open Cup).....80 + F. (27 C.) Furol viscosity at 122 F. (50 C.).....200 to 400 Distillation, per cent by volume: Total distillate to 374 F. (190 C.).....10+ Total distillate to 437 F. (225 C.).....20+ Total distillate to 600 F. (315 C.).....35— Tests on residue from distillation: Penetration at 77 F. (25 C.) 100 g., 5 sec... 60 to 120 Ductility at 77 F. (25 C.).....60+ Soluble in carbon disulfide, per cent.....99.5+

The road-mix pavement was constructed by following actual construction methods as nearly as possible. First, the stone was distributed by means of a spreader-box to a uniform, loose depth of about $2\frac{1}{2}$ in. Then, the track was divided into six equal sections, which were treated with a total of 2, 3, 4, $4\frac{1}{2}$, $3\frac{1}{2}$ and $2\frac{1}{2}$ per cent of cut-back asphalt in the order named. This order was used to eliminate any sudden change in the adjoining sections. The cut-back asphalt was sprayed in two applications of equal amounts. Immediately after spraying, the stone was thoroughly raked and turned over with shovels to simulate the action of a grader and to produce a uniform coating. The surface was then leveled with a strike-off board and allowed to cure.

After 24 hours of accelerated curing, followed by about 3 days' exposure to natural laboratory conditions, the surfaces were rolled. Immediately after rolling, the track was sprayed with $1/10$ gal. of cut-back asphalt per square yard, and stone chips, $\frac{1}{2}$ to $\frac{1}{4}$ in. in size and to the amount of 11.3 lb. per sq. yd. were broomed into the surface voids. The surface was rolled again; profile measurements were taken and the road was allowed to cure under natural laboratory conditions for 7 days.

TABLE II.—DEPTH OF RUTTING IN INCHES AFTER DIFFERENT NUMBER OF PASSES OF TIRE

Cut back Asphalt Per Cent	—Surface Dry—			—Surface Wet—	
	2650 Passes of Tire	5300 Passes of Tire	7050 Passes of Tire	2750 Passes of Tire	5150 Passes of Tire
2	0.24	0.31	0.37	0.43	0.61
$2\frac{1}{2}$	0.20	0.29	0.33	0.41	0.65
3	0.19	0.26	0.31	0.43	0.55
$3\frac{1}{2}$	0.24	0.34	0.35	0.43	0.54
4	0.21	0.29	0.34	0.45	0.63
$4\frac{1}{2}$	0.24	0.34	0.38	0.49	0.63
Average	0.22	0.30	0.35	0.44	0.60

The test for the stability of the above described pavement was made by subjecting it to the action of the loaded tire and measuring the amount of rutting in the pavement sections after a definite number of passages. The pavement was maintained at an arbitrarily chosen constant temperature of 90 F. (32 C.) throughout the test.

After about 7,000 passages of the tire an appreciable rut had developed. It was now decided to fill the voids in the pavement with water and to continue to run the tire. After 5,150 additional passages of the tire, with the pavement wet, the rut had become so deep and rough that the test had to be stopped because of the vibrations set up in the floor of the building.

The wheel running over the pavement saturated with water has the effect of pumping the water through the

voids, causing the asphalt to lose its adhesion to the aggregate. This last portion of the investigation may be considered as a durability test on this type of construction, especially when different aggregates and bituminous materials are thus compared.

It was apparent that the quantities of cut-back asphalt used in these test sections more than covered the range employed in this type of construction.

The results of these are tabulated in Table II.

From these tests and for the particular type of construction studied, the indications are:

1. That bitumen content, within a practicable range has no appreciable effect on the stability of the open-type road-mix pavement.

2. That water greatly accelerates the disintegration of open-type, road-mix pavements under the action of traffic.

Stabilizing Effect of Top Dressing of Screenings on Open-Type Bituminous Mixtures.—In a particular study of the stability of open-type bituminous mixtures containing various percentages of crushed fragments, a rather important fact was brought out which further demonstrates the great usefulness of the circular track testing device.

A test pavement of $2\frac{1}{2}$ in. loose thickness was constructed in seven sections, each of the same gradation, $\frac{1}{2}$ to $1\frac{1}{4}$ -in., round opening screens, and of the same asphalt content, namely, 3.3 per cent, but containing different percentages of crushed fragments. The track was rolled and cured for several days prior to testing under the action of the loaded tire.

After 120 revolutions of the wheel a rut developed of different depths for the seven sections but which averaged 0.19 in. in depth. In 189 additional revolutions, the rut averaged 0.33 in. in depth. All seven sections were comparatively unstable. The pavement was then reshaped and 12 lb. per sq. yd. of screenings were rolled into the surface of each section. The screenings had the following gradation:

	Total Retained, Per Cent
$\frac{3}{8}$ -in. screen	0
No. 4 sieve	61
No. 8 sieve	78
No. 16 sieve	92
No. 30 sieve	94
No. 50 sieve	95
No. 100 sieve	97

The loaded wheel was then run for 4,000 additional revolutions which resulted in an average depth of rut of 0.68 in. The rut developed very much more gradually in this test than in the preceding test, thus, demonstrating the great stabilizing effect of filling the surface voids with screenings.

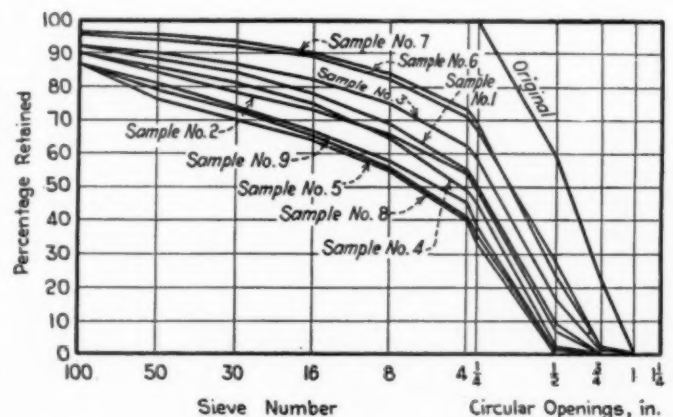


Fig. 9—Gradation Curves Before and After Roller Tests on Aggregate for Bituminous Surface Treatment

It is strongly indicated by this test that choking the surface voids in an open bituminous mix with screenings greatly adds to the stability of that mix.

Resistance of Aggregates to Crushing Under the Roller.—An investigation has been made to determine the relative resistance to crushing of several aggregates for surface treatment work. Most of these aggregates passed the routine physical tests specified; yet it was known that some of them crushed excessively under rolling action during construction. The following samples were included in the test:

Sample	Material	Wear (Deval Abrasion Test), Per Cent	Toughness ¹	
			Core A	Core B
No. 1.....	Granite	2.6	8	16
No. 2.....	Granite	1.8	15	15
No. 3.....	"Greenstone".....	1.7	12	15
No. 4.....	Limestone	3.5	5	5
No. 5.....	Granite	1.9	11	10
No. 6.....	Granite	1.7	24	25
No. 7.....	Limestone	2.9	7	7
No. 8.....	Granite	1.9	12	9
No. 9.....	Slag	Weight equals 78 lb. per cu. ft., rodded		

¹ Cores A and B drilled at right angles to one another.

It was decided to apply the following simple roller crushing test:

Nine equal sections about 5 ft. long were marked off in the track. The identically graded samples were laid in the track in a 1-in. loose layer and the roller passed over them 200 times in a single path at approximately 175 ft. per min. To prevent excessive creeping of the samples, 100 passes of the roller were made, followed by 100 additional passes in the reversed direction. Thickness measurements were made before and after test, and mechanical analyses were made on samples taken from the path of the roller.

The gradations before and after test are shown in Fig. 9. It will be noted that there is a definite grouping of the samples. Samples Nos. 6 and 7 show high resistance to crushing; samples Nos. 1, 2, 3 and 4 are intermediate; and samples Nos. 5, 8, and 9 are inferior. This is also shown on Fig. 10 where the percentage reduction in thickness of the layer is plotted against the percentage of material passing the No. 4 sieve, the latter percentage being used as an index of crushing. Appar-

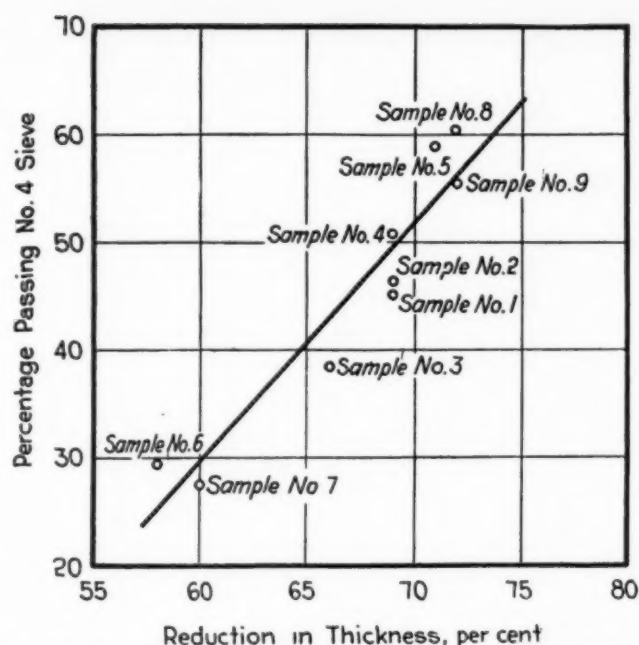


Fig. 10—Percentage Reduction in Thickness of Layer of Aggregates Under Roller Action

ently there is no relation between the Deval abrasion test results and the resistance to the roller, nor does there appear to be any relation between the toughness test results and crushing under the roller.

Figures 11, 12 and 13 show the appearance after rolling of a superior, intermediate and inferior material, respectively (Samples Nos. 7, 2 and 8).

The foregoing results show that the standard tests do not give an accurate indication of the resistance to crushing, and that a wide range of service results might be expected even with material satisfactorily passing the routine physical tests. It is believed that the roller test approaches actual service conditions and that the relative resistance to crushing so obtained is an indication of the relative merits of the materials for use where subjected to the crushing action of a roller during construction or of traffic.

TOP

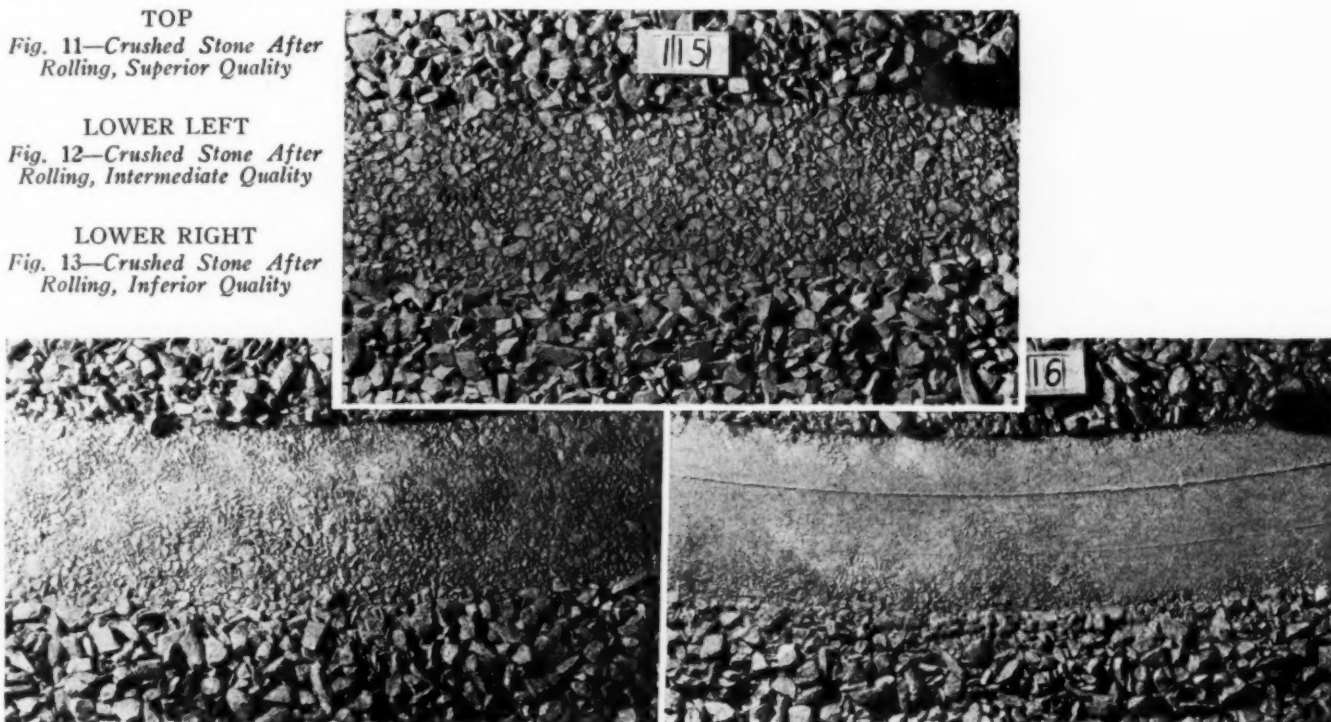
Fig. 11—Crushed Stone After Rolling, Superior Quality

LOWER LEFT

Fig. 12—Crushed Stone After Rolling, Intermediate Quality

LOWER RIGHT

Fig. 13—Crushed Stone After Rolling, Inferior Quality



Investigations on Cold Lay, Liquefier Type of Bituminous Mixtures.—Several problems have arisen in connection with the cold lay liquefier type of bituminous pavement. There seems to be no unanimity of opinion among engineers as to: (a) the gradation of stone for use in the base and top courses, (b) the most desirable type of liquefier, and (c) the most favorable proportions of the mix as between the several ingredients, including stone, asphaltic cement, liquefier and hydrated lime. The present investigations have been conducted primarily to obtain some indication of the best gradation of aggregate for the maximum stability under traffic and for the maximum durability under wet weather conditions involving rubber-tired traffic.

Some cold-mix plants ship the mixture into adjoining states and it is expensive and uneconomical to make widely varying mixtures in the same plant. Consequently, if there is a limited range of gradation which gives the most favorable result, it would be desirable to determine what that range is. Ease of handling and workability as well as serviceability are important considerations in mixes of this type.

Tests of Cold Lay Mixes.—The specifications of four adjoining states were analyzed and the limitations of gradation were determined for both the base and top courses. These ranges are shown in Table III, for the base courses and the top courses, respectively. Mixes were prepared in the laboratory by carefully grading the stone in accordance with these gradations, and mixtures were made up having the ingredients shown in Table IV.

For each of the four state specifications, three mixtures were made, involving the coarsest, the finest and the intermediate aggregate gradations. The intermediate gradation was made up as the average of the extremes of gradation. The coarsest top mix was used with the coarsest base mix in all cases and, similarly, the finest and intermediate bases and top courses were combined.

After laying and rolling the bases, they were cured

TABLE IV.—REQUIREMENTS FOR COLD LAY LIQUEFIER TYPE BITUMINOUS CONCRETE IN FOUR ADJOINING STATES.

	Fine, Medium and Coarse Gradations.					
	Section No. 1	Section No. 2	Section No. 3	Section No. 4	Section No. 5	Section No. 6
Base Course						
Aggregate, per cent ...	92.0	93.55	95.1	92.2	93.75	95.35
Liquefier, per cent	1.0	0.7	0.4	1.0	0.7	0.35
Lime, per cent	1.0	0.75	0.5	1.0	0.75	0.5
Asphalt cement, per cent	6.0	5.0	4.0	5.8	4.8	3.8
Top Course						
Aggregate, per cent ...	90.0	92.05	94.1	91.0	92.57	94.15
Liquefier, per cent	1.0	0.7	0.4	1.0	0.68	0.35
Lime, per cent	1.0	0.75	0.5	1.0	0.75	0.5
Asphalt cement, per cent	8.0	6.5	5.0	7.0	6.0	5.0
State C						
Base Course						
Aggregate, per cent ...	93.5	95.0	96.6	91.2	92.9	94.6
Liquefier, per cent	1.5	0.95	0.4	1.3	1.1	0.9
Lime, per cent	1.0	0.75	0.5	2.5	2.0	1.5
Asphalt cement, per cent	4.0	3.3	2.5	5.0	4.0	3.0
Top Course						
Aggregate, per cent ...	91.5	93.3	95.1	89.2	90.5	92.1
Liquefier, per cent	1.5	0.95	0.4	1.3	1.1	0.9
Lime, per cent	1.0	0.75	0.5	2.5	2.0	1.5
Asphalt cement, per cent	6.0	5.0	4.0	7.0	6.25	5.5

until the free liquefier was driven off. The top courses were rolled and cured in a similar manner. The test pavement was then subjected to the loaded tire running in a single path.

Results.—The results, expressed in terms of the average amount of rutting which occurred in the various sections, are shown in Fig. 14. It is noticeable that a wide range in stability existed. Mix No. 10 was particularly unfavorable. It was finely graded and was the heaviest and densest mix in the various sections. There is not much to choose in stability in the remaining sections as judged by the amount of rutting produced under dry conditions. Sections Nos. 3, 6, 9 and 12 contain the most open mixes in the respective specifications and under wet conditions sections Nos. 3, 6 and 9 seem to be the least durable and section No. 10 the most durable. Sections Nos. 4, 5 and 6 were the most resistant and best sections considering both stability and durability.

The above tests are preliminary and are only a small

TABLE III.—EXTREME GRADATIONS OF AGGREGATES POSSIBLE IN FOUR DIFFERENT STATE SPECIFICATIONS.

	Square Openings State A		Round Openings (1/4-in. to 2-in. Screens) State B		Round Openings (1/4-in. to 2-in. Screens) State C		Round Openings (1/4-in. to 2-in. Screens) State D	
	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse
Base Course of Cold Lay Liquefier Type of Mixtures								
Total retained on 2-in. screen, per cent ..	0	0	0	0	0	0	0	0
Total retained on 1 1/2-in. screen, per cent ..	13	32	5	25	18	32	13	32
Total retained on 1-in. screen, per cent ..	0	0	40	62	35	59	40	66
Total retained on 3/4-in. screen, per cent ..	47	62	62	83	60	85	50	77
Total retained on 1/2-in. screen, per cent ..	73	95	..	..	..	..	..	..
Total retained on 3/8-in. screen, per cent ..	79	96	70	87	69	90	65	92
Total retained on 1/4-in. screen, per cent ..	93	96	83	93	85	99	73	92
Total retained on No. 10 sieve, per cent ..	95	97	87	95	89	99	80	94
Total retained on No. 30 sieve, per cent ..	97	98	93	96	94	99	85	96
Total retained on No. 80 sieve, per cent ..	99	99	98	99	98	100	89	97
Top Course of Cold Lay Liquefier Type of Mixtures								
Total retained on 1-in. screen, per cent ..	..	..	..	..	..	..	..	0
Total retained on 3/4-in. screen, per cent ..	..	..	..	0	..	..	..	3
Total retained on 1/2-in. screen, per cent ..	0	0	0	4	0	0	..	5
Total retained on 3/8-in. screen, per cent ..	14	22	12	20	10	16	0	7
Total retained on 1/4-in. screen, per cent ..	50	80	63	85	55	85	37	65
Total retained on 3/8-in. screen, per cent ..	91	95	..	..	..	..	..	..
Total retained on No. 10 sieve, per cent ..	92	96	74	89	67	89	70	86
Total retained on No. 30 sieve, per cent ..	96	98	85	94	82	94	80	92
Total retained on No. 80 sieve, per cent ..	98	99	97	99	97	99	88	95

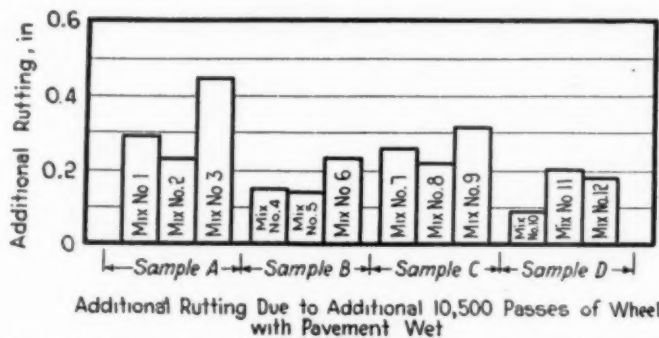
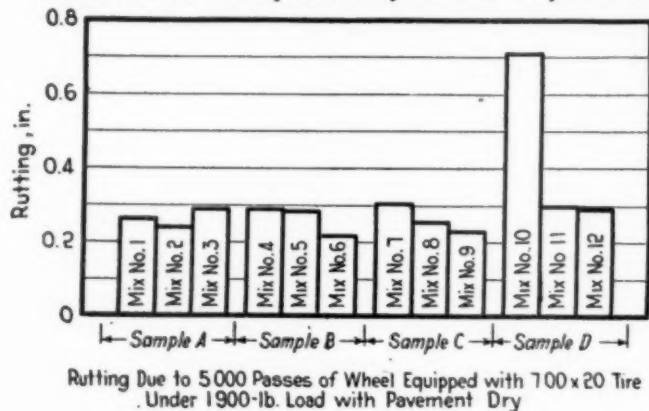


Fig. 14—Chart Showing Relative Stability and Durability of Cold-Lay Liquefier Type Mixes

portion of a more comprehensive series of tests on cold lay mixtures. These tests are too extensive to be considered further at the present time.

Conclusion.—It was not the intention in the present paper to draw definite conclusions from the various tests which have been described briefly, but rather to show the wide range in applicability of a testing device of the circular track type. The machine was built originally as a device for testing the stability of different types of pavement mixtures, but it has many more possibilities and is extremely useful for studying other problems involving road materials.

The roller attachment approaches actual rolling conditions during construction, and is very useful for studying the resistance of aggregates to the crushing action of the roller. Thus the various physical tests conducted on aggregates may be checked against service results. Since the action of the rubber-tired wheel is similar to that of traffic, service tests for stability can be made. Furthermore, by the use of chains on the tire, the resistance of various kinds of surfaces to the action of this type of traffic may be studied so as to obtain comparative results. Here, again, such results are useful in correlating the regular physical tests of aggregates with service behavior.

The track may be flooded with water and subjected to traffic and, thus, the action of various aggregates in the retention of their bituminous film may be studied.

Finally, with this equipment, it is quite possible to

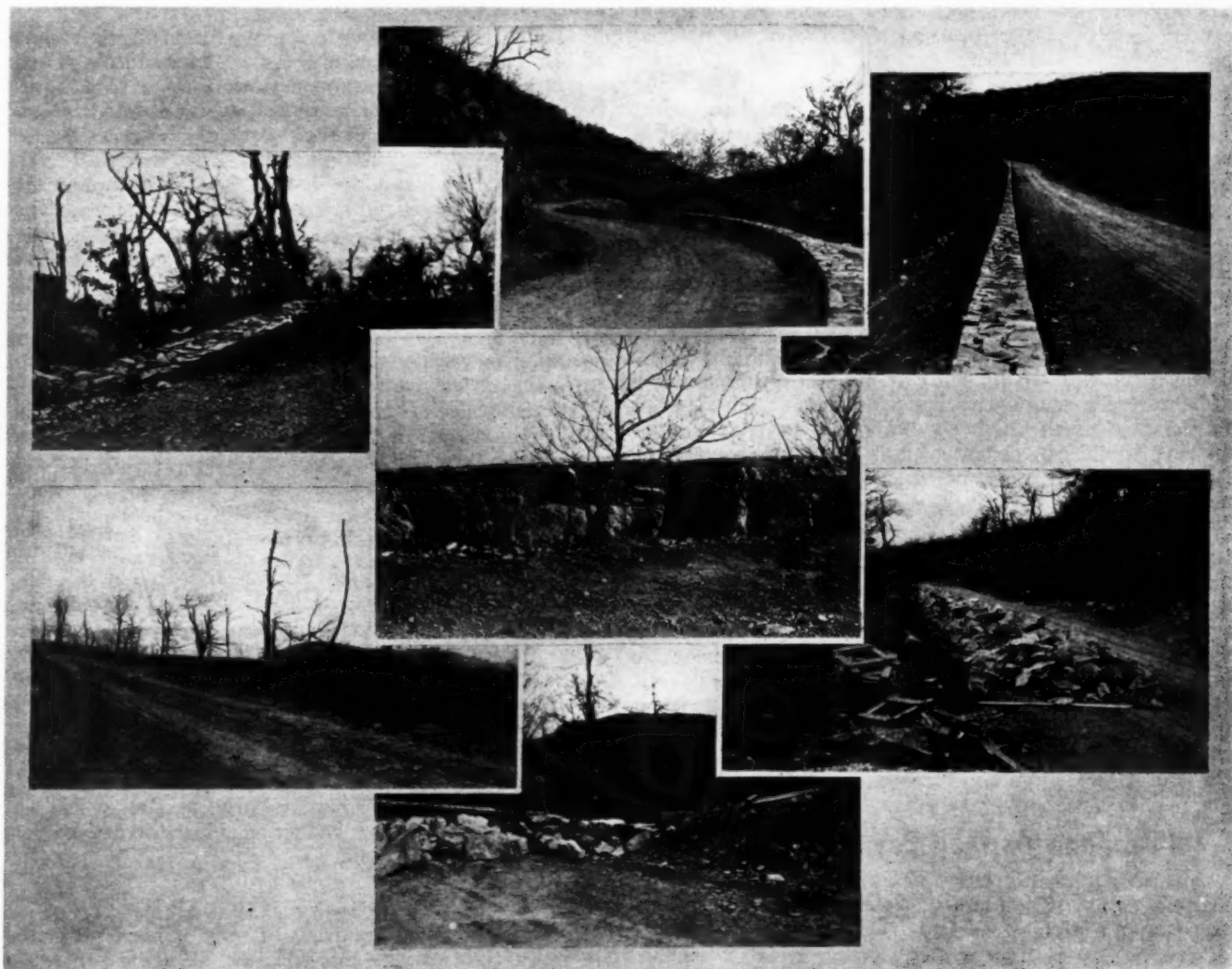
freeze the surfacing material and then subject it to traffic upon thawing.

From the foregoing it is apparent that the circular track testing machine is an excellent tool for quickly coordinating laboratory physical tests with service behavior and for determining rapidly the service value of highway materials and their combinations.

Acknowledgement.—The foregoing is a paper presented at the 37th annual meeting of the American Society for Testing Materials, held June 25-29 at Atlantic City, N. J.

New Alpine Highways Proposed

It is reported that a referendum on a project for the construction of new roads across the Swiss Alps is to be held soon and the indications are that it will carry. The state owned railways of Switzerland have been inclined to view automotive transportation as a serious competitor. This has tended to retard the movement for better highways. On the other hand, groups in favor of new automobile roads have lately been advocating such projects as a form of productive unemployment relief. Recent relations between Germany and Austria have strengthened the movement for new Alpine all year roads between Switzerland and Italy. Through tourist traffic from Germany to Italy which has greatly increased, is another inducement for the Swiss to plan new routes of travel.



Guard Rail Built of Rubble Stone on the Skyline Drive in Shenandoah National Park. This Road Was Built Under the Supervision of the U. S. Bureau of Public Roads—1933 Photo—Road Not Yet Open to Traffic.

High Salvage Value of Timber in Nueces Bay Causeway

Official reports of the Texas State Highway Department concerning the recent completion of the work of reconstructing the causeway across Nueces Bay at Corpus Christi, necessitated by hurricane damage in the fall of 1933, disclosed a remarkable instance of salvage value of timber.

In September, 1933, the Southern coast of Texas, including Corpus Christi, was swept by a severe hurricane, the worst since the fall of 1919. When the storm passed a survey of the damage was made. Among other things it was found that the all-timber causeway across Nueces Bay, one and one-eighth miles long, had been badly damaged, as it had been battered by the force of the hurricane and water for three days, most of that time being completely submerged.

This causeway had been constructed following the 1919 hurricane in the Corpus Christi area. It was constructed entirely of treated longleaf Southern pine, requiring 1,423,000 board feet, including piling, planking, rails, etc.

The Texas highway engineers' survey of the damage done to the timber causeway by the September, 1933, hurricane, disclosed that nearly all the longleaf pine piling was still in place, although some of it had been forced out of line. But most of the flooring and railing had been torn loose from the piling and washed up the bay. The highway engineers decided to rebuild the bridge in exactly its previous form, using all the salvaged material possible.

Forty days after the work was started, the rebuilding of the bridge was finished and it was opened to traffic. This rapid reconstruction, it is said, was made possible because of the fact that 87 per cent of the original lumber and piling was found and salvaged. Some of the material had washed as far away as ten miles from the bridge site, but it was found in good, sound condition, brought back and used in the rebuilt structure.

Paralleling the highway causeway at a distance of about 100 yards is a railroad bridge also constructed out of treated Southern pine. This railroad bridge was virtually undamaged by the 1933 hurricane as the openings between the ties on top allowed the storm-driven water to be forced through with but little shock to the trestle. In the case of the highway bridge, however, the tight flooring would not permit of this and consequently the flooring and other portions of the structure received the terrific battering of the wind-borne waters.

The 13 per cent of new lumber that was purchased for the reconstruction of the highway causeway, it was said, did not represent the quantity of material actually damaged to such an extent that it could not be used again, but rather the material that was lost by being washed out into the Gulf of Mexico or into inaccessible marshes. The entire cost of rebuilding the bridge was reported to be \$78,000, of which sum \$32,000 was spent for new lumber. The Texas engineers cite this case as an exceptional instance of salvaging material for a project of this size and character.

Cast Iron and Asphalt Paving

The municipal authorities of Duisburg-Hamborn, Germany, are to construct an experimental highway in which cast iron grating is to be used. The highway will consist of a base or sub-structure with a thin layer of asphalt, upon which cast iron grates 2 centimeters high will be placed. These grates will be filled with asphalt.

Bids on Federal Contracts

Regulations governing bids on public contracts have been modified sharply by an Executive order of June 29 to permit all bidders to offer Government agencies prices as much as 15 per cent below the quotations publicly filed by them under the open price provisions of their Codes. "Public contracts" includes those awarded by agencies of state, municipal, and other public agencies as well as by the Federal Government.

Application of the order is specifically limited to industries which are Code-bound to bid in accord with previously posted prices and it in no way alters other regulations adapting Government purchasing policies to the rules of NRA Codes.

The modification order does not authorize the breaking of posted open prices in bidding on private work, Code regulations remaining in full control. But, for protection of both the industry and its consumers, the order requires that whenever a firm cuts below its posted price in bidding on Government work, it must, immediately after the bids are opened, file a copy of its bid with the appropriate price-reporting agency. However, the previously posted prices will remain in force until and unless changed by their makers.

Private customers having access to the posted open prices will also have access to the filed bids and will therefore know exactly what prices are being quoted to the Government and, it is expected, will guide their purchasing policies accordingly.

The direct effect sought by the order is to restore, within a reasonable range, the price competition of true sealed bids on all Government work without undoing the beneficial effects of price reporting Code requirements. The new rule was instituted to meet the repeated complaints of public purchasing agents who, though directed by law to buy from the lowest bidder, have been insistently confronted with identic bids, set in accordance with previously filed open prices. Many Codes have required such a course, with no freedom for bidding firms to depart from the effective price level thus established.

To take care of cases in which the full 15 per cent variation may cause damage to an industry's price structure, the order provides that if complaint is filed, the Administrator for Industrial Recovery may after due investigation and finding of the facts reduce the allowable percentage, but in no case to less than 5 per cent below the posted prices.

A study and report on operation of the new plan is required to be made within 6 months.

EIGHTEEN THOUSAND MEN NOW WORKING ON MINNESOTA HIGHWAYS.—Employment is now being provided for approximately 18,000 men by the Minnesota highway department, according to a statement dated August 1 from N. W. Elsberg, commissioner. Road jobs are under way in practically every county in the state.

Nearly all the construction in progress is being paid for with federal funds granted the state last year. The grant this year is only half as large as last, which will mean a corresponding reduction in construction next season, Mr. Elsberg said.

FARMERS GIVEN ROADSIDE HAY.—Minnesota farmers also have harvested hundreds of tons of hay from trunk highway right-of-way this summer. Wherever there are stands of grass or hay along the roadsides it has been offered free for the cutting to farmers on abutting land.

Fig. 1—Deposit of Sandstone in Which the Bedding Planes Are Very Marked



Fundamentals of PRACTICAL ENGINEERING GEOLOGY

FOR the past 15 to 20 years, geologists have been largely instrumental in elevating the mining, oil and gas industries to their present state of effectiveness. Great wealth has been obtained from the earth by the geologists in their study and interpretations of surface and sub-surface structure. It is believed that some phases of the science of geology should be applied more generally to engineering activities, particularly to highways, water supply, and other civil engineering work. In the current curricula of civil engineering courses, students secure only a limited amount of instruction in the science of geology. Accordingly, this article is written with the attempt to present some of the geological features that engineers should be familiar with and should utilize. The raw material which enters into the manufacture of cement, the location of a new highway, the rock quarries, the sand-gravel pits are all intimately related to the science of geology. Some may consider that highways are outside the scope of geology, but the economic value producible by the careful and judicious locating of these roads is important in relation to their service life. Consider, too, the great number of quarries in the United States. How many of the operators know the condition of their holdings, especially with respect to the extent of the deposit, uniformity of the material and other all-important qualities. It is the purpose of this brief article to point out and to illustrate where the applications of geology might be the means of saving time, effort and money.

Some Geological Observations.—In almost any part of the United States it is possible to find one or more varieties of rock, either as outcropping ledges or as boulders. The chief exception to this statement is the areas in the middle western part of the country where the land is level and little opportunity exists for rock outcrops.

Outcroppings are to be especially noted in natural and artificial cuts upon highways, railways and streams and in locations where landslides have occurred. In these locations either man or nature has exposed the rock so that its texture, stratification, if any, and other features may be studied in detail. If study is given to the rocks so exposed, it will be noted that they are either "bedded"

and lie layer upon layer, or they will have no bedding. This latter condition is illustrative of the "massive" variety of rocks. There is a third variety which exhibits characteristics of both bedded and massive types which are termed metamorphic. If the exposed rocks are examined still further, the bedded material will be seen to consist of extremely fine particles, or large particles which have become rounded or sub-angular. In general, these rocks are limestone, sandstone, chert, etc. Coincident with the beginning of time, detritus derived from existing land forms were collected and deposited upon the ocean floors. These layers have ultimately become compacted into solid rock. Figure 1 illustrates a stratified bed of sandstone.

If samples of the massive variety of rock are examined closely, it will be found that the individual grains are not rounded or sub-angular, but have definite crystal-formed faces and angles. This indicates a previously existing liquid state of their mineral matter. The best way to visualize what has taken place during the formation of massive rocks is to examine a piece of lava which has solidified. This material was once viscous molten magma, and flowed slowly from vents in the earth's crust to finally crystallize as solid rock. In other cases the magma congealed at greater depth in the earth's crust, and through subsequent erosion of the overlying rock formations became exposed to the light of day.

Another item of importance concerning the exposed rock is whether the beds, if bedded rock, are horizontal or are inclined. The amount of the inclination from the horizontal can be estimated with the eye, but a clinometer is used to obtain a more accurate determination. The angle which the strata make with the horizontal is termed the *dip*, and the direction in which the exposed strata extend is termed the *strike*. Figure 2 illustrates the application of these terms to strata.

Since the massive rocks have not been deposited layer upon layer like the bedded varieties, their structural fea-

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tures are of a different kind. The size and shape of massive rock formations were, in many instances, incidental to and dependent upon existing rock formations, either bedded or massive. Not infrequently the massive rock exists as intrusive material within a rift, fissure or crack producing the feature known as a dike. Figure 3 shows a dike formation, in which a granite-like rock, called aplite, is intruding into sedimentary rock. It frequently happens that the rock materials previously existing is more easily weathered than the massive formation and in consequence the dikes protrude above the surrounding weathered rock material, or in some instances the latter has entirely disappeared.

Geologic Structures.—Sedimentary strata have been deposited in quiet waters and consequently formed horizontal layers. However, during geologic upheavals or other orogenic movements, these layers have become folded and faulted into various shapes and positions. Quite often beds have been so tilted that they stand vertically, while in other locations remarkable instances of buckling, twisting and other distortions are found. In Fig. 4 is shown several of the more common types of folds and faults. It is of practical importance to take note of these folds, synclines, anticlines, etc., as they are often misleading when calculating available material or the recoverable minerals. In quarrying operations it is particularly important that these features be mapped and examined. Furthermore they are important factors to be considered in making cuts, since they may influence the development of slides either during the progress of construction operations or at subsequent periods. Incidentally their influence upon the movements of water within the rock mass has frequently been an important element in the development of destructive and costly landslides which have not infrequently involved losses of human lives.

Quite often the massive rocks will form such structural features as sills, laccoliths and bosses, etc. When the massive rocks run parallel to the bedded rock the structure is called a sill. It is relatively thin as compared with its great lateral extent and theoretically it thins out at the edges, but this feature is seldom visible. A laccolith is similar to a sill except that the ratio between its

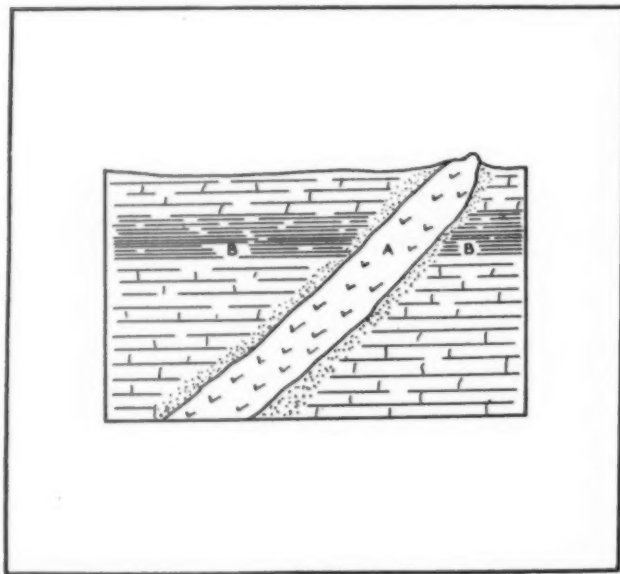


Fig. 3—Dike of Igneous Material Intersecting Bedded Rock. Note Contact Zone between Dike and Adjacent Rock. A: Dike. BB: Bedded Rock

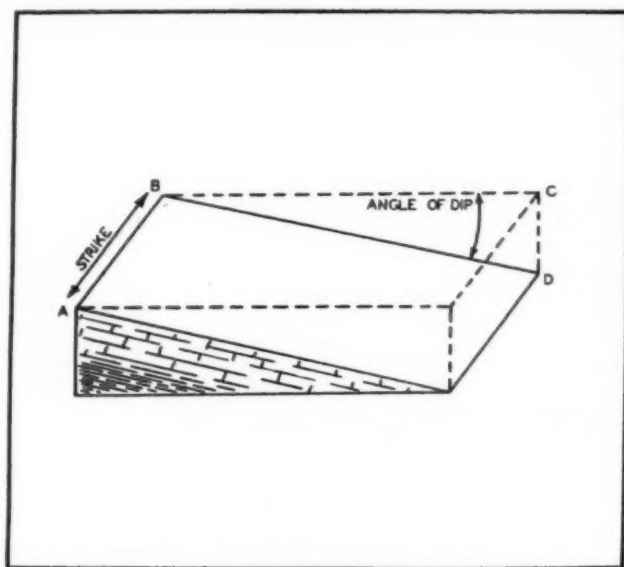


Fig. 2—Diagram Illustrating Dip and Strike. AB: Strike. CBD: Angle of Dip

thickness and its width is greater, and its roof is distinctly dome-shaped. A boss is produced by being originally surrounded by bedded rock, but has become exposed by the weathering away of the overlying material. The geologic history of a region can be quite thoroughly identified by the types and forms of the existing rocks. However, much of this historical record may have become lost through weathering during undeterminable lengths of time.

Types of Rock.—Of practical importance to the engineer is a thorough knowledge of the three types of rock known as, (1) igneous, (2) sedimentary, and (3) metamorphic, since they are involved to a major degree in his construction operations. Brief descriptions of the origin and composition of these rocks have been published by the writer in a series of articles¹, and so will not be discussed in detail at this time. However a brief description of the three types follows: Sedimentary rocks are those which have been derived from the existing land forms and have been deposited in layers by water or wind. The chief siliceous members are sandstones and chert, while the main calcareous varieties are limestone, dolomite, marl, etc. The igneous or massive varieties of rock, are those which have solidified at or near the earth's crust from molten magma which has been squeezed from the earth's interior into the upper portions of the crust. The chemical composition of this magma determines just what the final rock, when crystallized, will be. Among the igneous rocks used in engineering works are granites, syenites, diorite and the "traps."

Metamorphic rocks are those of either sedimentary or igneous origin and which have been altered by the effect of temperature and/or pressure. The existing rocks which have been altered by heat alone have undergone some chemical rearrangement of the constituents to those of a new and distinctly different kind. In other words, the structure of the rock has not been altered as much as has been the mineral components. However, in dy-

¹The Origin and Composition of Igneous Rocks, *ROADS AND STREETS*, Vol. 77, No. 5, May, 1934.

The Origin and Composition of Sedimentary Rocks, *ROADS AND STREETS*, Vol. 77, No. 2, February, 1934.

The Origin and Composition of Metamorphic Rocks, *ROADS AND STREETS*, Vol. 76, No. 11, November, 1933.

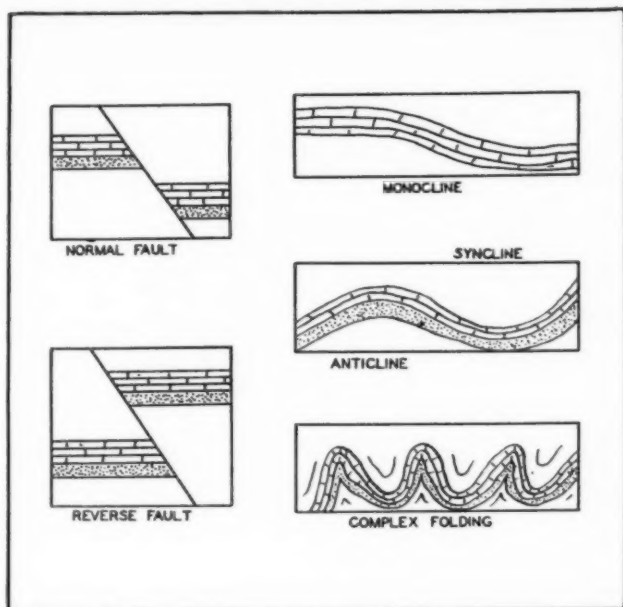


Fig. 4—Some Examples of Folding and Faulting

namic metamorphism, or that caused by stress, the crystalline structure, as well as the mineral composition has been altered. Among the metamorphic rocks considered as having construction value are, marbles, quartzites, gneisses, amphibolites, etc. Incidentally, we recognize that the engineer is not so much concerned with the genetic origin of these rocks, as he is in utilizing them now that they are available. Accordingly, the standard text-books are suggested as references if one desires complete information of the life history of these rocks. A few selected texts, wherein this information may be found, is appended to this article.

The foregoing observations and descriptions embody in brief the essentials requisite to an understanding of the fundamentals of geology as related to rock materials. The application and utilization of these essentials in relation to engineering structures is, we venture to believe, important alike to both engineering design and construction and, therefore, should prove of equal interest to engineers and to contractors engaged in engineering construction, since both are concerned with the utilization and handling of our natural rock resources.

The Practical Value of Geology.—It not infrequently happens that contractors, rather than engineers, determine the location where rock quarries and sand-gravel pits are to be developed for securing materials to be used in highway and bridge construction. A fairly accurate determination of the quantities of materials available is, in such cases, an important economic factor. Two instances in highway construction will serve to demonstrate this importance of material site surveys. In one of these cases a contractor had made a rather superficial examination of a location in which supposedly suitable material was available adjacent to the highway right-of-way. The equipment was installed with the intention of producing large quantities of crushed rock. The exposed surface of the rock formation gave fair promise of satisfactory material. The rock was a siliceous limestone and a laboratory sample secured therefrom had satisfactorily passed the tests for the type of construction in which it was to be used. Shortly after quarrying had been started and several feet of material had been shot down, it was discovered that the limestone formation was running into a limy shale, which was totally unfit for road building purposes. If the contractor had examined the

site a little more carefully, or had consulted a geological engineer, he would probably have been spared considerable loss of time and expense. Fig. 5 shows the elevation of the rock location and the conditions which actually existed at this place.

In another instance it was desired to locate some local rock for use in surfacing a highway. Rock of suitable quality was located about three miles from the construction work, involving a haul over an unimproved dirt road. It later developed that this same rock formation was near the earth's surface along the highway to be improved, and was only prevented from outcropping by a thin layer of talus, or surface debris. Had a geologist or an engineer, having a practical knowledge of geology, examined the site; the extension of the formation would have been anticipated and discovered, thus entailing a saving in time and expense. A diagram illustrative of the conditions as described above is shown in Fig. 6.

Incidentally, the foregoing instances specifically direct attention to not only economic advantages securable by geological considerations in relation to the securing of materials but also point the way to other advantages and economies securable by having proper material site surveys made prior to inviting contractors to submit competitive bids for work to be done. The elimination of elements of uncertainty is invariably reflected in the prices bid for any given project. When more than one location can be designated as acceptable material sources of supply, this information will supply contractors a choice of the one which may be best fitted to his available equipment.

From the engineer-geologist's point of view, competence in determining the geology of a given area and visualizing nature's processes incidental to its creation, including the carving of its topography will permit him to adopt in his design of the location of a highway, a railway, a dam site and other structures almost too numerous to mention, construction details insuring stability and permanence. Fig. 7 illustrates the influence of the dip of strata in producing slides. The existence of percolating water within the joint planes frequently becomes a controlling factor in producing movements. Shand states² that a frequent cause of trouble in large surface

²Useful Aspects of Geology, by S. J. Shand, p. 175.

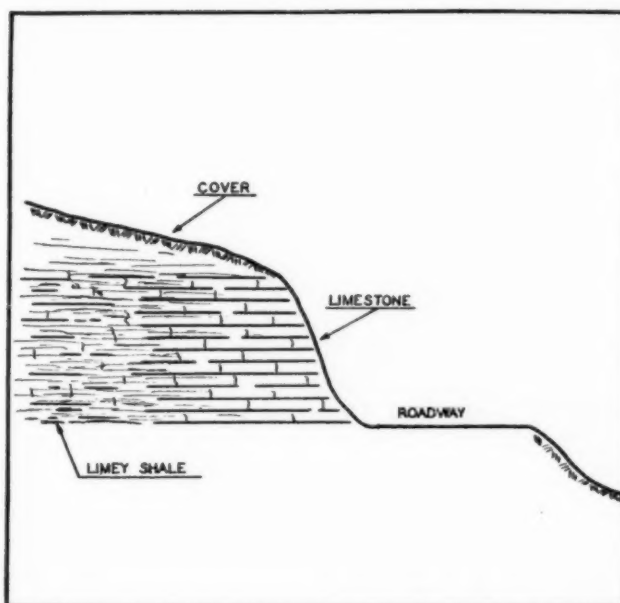


Fig. 5—Elevation of Quarry Site Showing the Change in Character of Solid Limestone into Limy Shale

works is earth-creep, which culminates in extreme cases, in destructive landslides. The loose rubble on hillsides creeps slowly downward under its own weight, if the angle of slope is more than about 30 degrees, and when the material is saturated with water, a much smaller angle of slope will give rise to sliding. If a hillside is built up of alternate hard and soft beds, such as sandstones and claystones, and the dip of the beds is in the same direction as the slope of the ground, then the presence of the ground-water in unusual quantity after heavy rains may so lubricate the clay partings as to permit the overlying beds to slide over them.

A feature of highway construction which should not be overlooked is the excavation or cutting along the slopes of hills. Care should be exercised in the adoption and use of construction methods and procedures avoiding, so far as practicable, conditions tending to shatter or loosen the natural formations of the strata and the removal of their supporting material. In any specific case the kind and character of the material or materials should be closely examined. Clay has a high affinity for water, so that when wet it develops a plastic condition conducive to slide action. Glacial material, such as till, may be stable in dry weather but probably would slake during the wet seasons. Hard rock will usually stand at a very high angle, but certain inherent features, such as joints, or bedding planes, are likely to cause trouble especially if they dip toward the cutting. Investigation of these and other factors contribute to initial savings of labor and expense and insure future stability and safety.

In quarrying operations the extent of the deposit, its variations in geological formations, in character of the materials, the amount of stripping to be done and the quantity of unsatisfactory material to be wasted, etc., contribute to the ultimate economy of operation. The outcrop of rock material combined with an application of the information that experience only can provide will frequently prove sufficient, but work contemplating rather extensive operations combined with a corresponding expense for plant and equipment should involve a thorough study of the topography, streams, dip and strike of the strata and finally drill records. This feature serves as a final check in the observation. The drill holes should be so spaced as to provide the definite in-

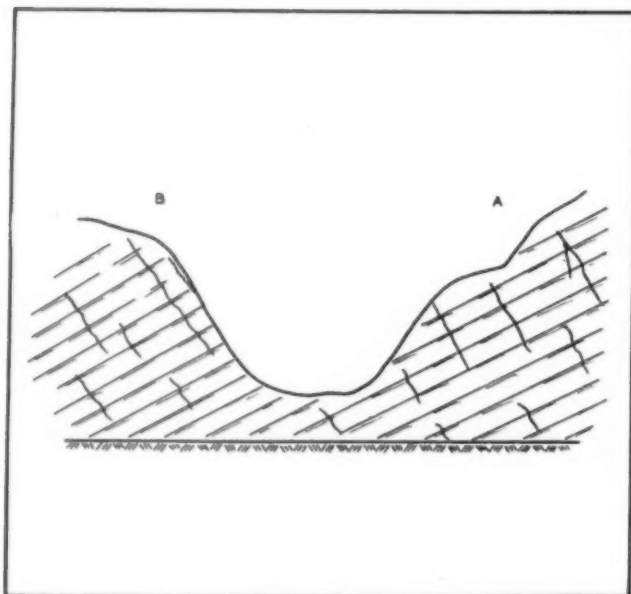


Fig. 7—Conditions Under Which Landslides Are Likely to Happen. At "A" the Bedding Planes May Act as a Sliding Surface, While at "B" the Principal Joints May Act in the Same Way (After Shand)

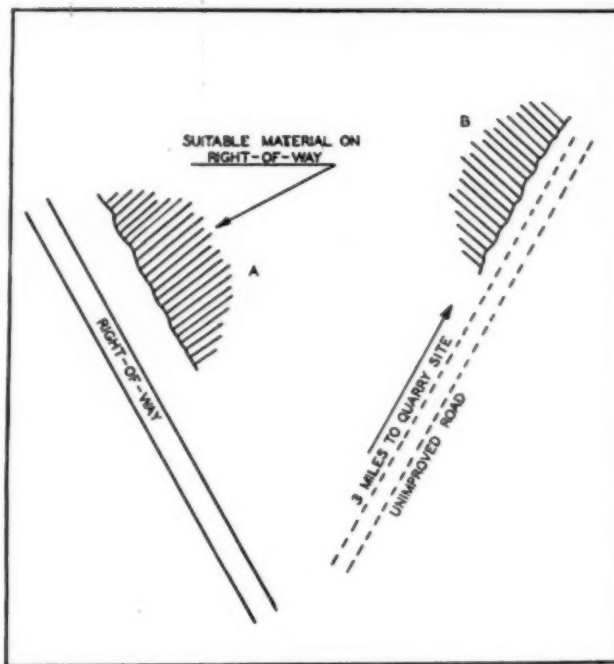


Fig. 6—Plan of Quarry Layouts. Material at Location "A" of Exactly the Same Character as That at "B"

formation with respect to outlines of the deposit. Furthermore, the drill holes should be so spaced as to produce the maximum amount of information with a minimum amount of drilling. The churn type of drill is used extensively, while both the diamond and shot drills permit the securing of cores which are strictly representative of the deposits. Naturally, the marketability and transportation facilities are prime requisites in the development of any quarry site. It is believed that a thorough geological investigation of any proposed site will well repay the operator.

Engineers interested in developing and increasing their knowledge of geology will find it profitable to visit dam sites, reservoirs, etc., where excavation work is in progress or has been completed. Whenever opportunity offers, these engineers should visit quarries, sand and gravel plants and other construction activities providing means of observing work and earth formations and they should familiarize themselves with the various classes of rock material by the examination of mineral collections in museums. Many engineers have found that the accumulating of private collections of minerals, fossils, photographs of glacial and other formations, geological maps and other pertinent information, is distinctly advantageous in extending their practical knowledge of geology and its direct relation to engineering operations.

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▼
TRUCK LESSORS AND NRA.—Lessors of motor trucks come definitely under the trucking code if they retain responsibility for the maintenance of the vehicle or the employment of drivers, the NRA has ruled. The decision bore the signature of G. A. Lynch, Administrative Officer.

STATE REQUIREMENTS

▲ ▲ For Bidders on Highway Contracts

THE public official responsible for the award of contracts and execution of work has always been faced with serious responsibility, in that while he had no choice in the selection of those who might care to submit proposals for performing the work, at the same time he was held responsible in public opinion, at least, for the satisfactory completion of the project.

As long as the only requirement was the ability of the bidder to furnish a certified check and a bond, after the award of the contract the hands of the official were to a very great extent tied. With the ability to furnish a certified check and bond as the sole measure of responsibility many evils cropped up in the award of contracts for the construction of public works. No matter how sincere the official might be it was not possible, in the short length of time elapsing between receipt of bids and award of contract, to make a proper investigation of the ability of the contractor.

Among the evils which became common was the bidding in of large amounts of work by firms having little or no organization or equipment with which to perform the contract in case it was awarded to them. These firms would then proceed to shop around until they were able to find one or more sub-contractors who would be willing to take the work at a lower price than they had originally bid. The result would be a poorly executed job, often obtained only by the most strenuous efforts on the part of the engineer.

Defaults in execution of the work and unpaid bills were common occurrences, not only on part of the sub-contractors but often on part of the main contractor as well. Work was not completed within the time specified, resulting in loss to the public through detours and inability to make use of the proposed improvement.

The responsible contractor, who had at his own expense maintained an efficient organization and equipment proper to perform any work upon which he might submit proposals and be awarded contract, was handicapped in securing such work on account of the fact that the individual or firm who expected to sub-contract the work to others would submit a proposal so low that he could not compete and adequately maintain his organization and equipment. Failures and defaults were common, and while the bonding companies in most cases were able to complete the work the public was deprived of use of the improvement, and satisfactory execution of the work was obtained only after great difficulty on the part of the department responsible for carrying out the improvement.

By J. T. ELLISON

Chief Engineer,
State Highway Department
of Minnesota

Wisconsin Pioneer State in Prequalification.—The State of Minnesota was not in any sense a pioneer in the prequalification and advance rating of contractors. In so far as the Middle West was concerned I believe that Wisconsin was the pioneer state in this respect.

The first prequalification rule of the Minnesota Highway Department was put into effect in May, 1929. Since then there have been certain changes made from time to time with view of working out some of the difficulties which were encountered in the rules as first submitted.

The first regulation covered only grading and paving, and provided that no contractor who had not previously worked for the department could bid upon or be awarded contract to build more than ten miles of 18-foot pavement or more than 160,000 cu. yds. of grading. No firm, even though they might have performed a considerable amount of work for the department in previous years, was permitted to bid who had not submitted to the department statements on the standard form covering finance, equipment and experience. The part of the statement requiring the closest scrutiny was that dealing with finance, as it has been our experience, to say the least, that most of the contractors are extremely optimistic as to the amount of work they can accomplish with little or no ready cash. It was not, or is it at the present time, a requirement that these financial statements be submitted by a certified public accountant, but we are seriously considering the making of such a regulation.

Required on Practically All Work in Minnesota.—The original requirements were gradually made more rigid and extended until in 1931 prequalification was required on practically all classes of work. At that time the rule was that if a contractor had not performed work in Minnesota the maximum amount of paving on which he could submit a proposal was 100,000 sq. yds. and the maximum amount of grading 200,000 cu. yds. These rules applied to every contractor and no credit was given a contractor for experience gained or work constructed in any state other than Minnesota.

At the same time more definite maximum limits were set on the contractor who had already been previously

qualified and a statement was issued showing exactly the maximum amount of work which might be awarded to any particular individual or firm. Acting under these rules and regulations proposals were received for somewhat over 100 miles of paving in November, 1931, and although the prices were approximately 5 per cent higher than the department estimate the contracts were awarded.

In December, 1931, proposals were requested on about 200 miles of concrete pavement. These bids were found to be higher than those received in November and were also higher than the department estimate, consequently all bids received at that letting were rejected. In April, 1932, approximately the same jobs were again advertised and satisfactory bids were only received on 4 of the 12 projects. Contracts were awarded on the four projects and bids on all the remaining work were rejected.

Shortly after this the Bureau of Public Roads issued a memorandum advising that any contractor who had satisfactorily completed Federal-aid projects in any state would be considered as qualified to bid on Federal-aid projects of similar size and character in any other state. This rule was accepted by our department and made effective not only on Federal-aid projects but on all state work as well, as we did not wish to have one set of rules for qualification applying to Federal-aid work and a different set applicable only to state work. Our rule at the present time, therefore, is that a contractor who has not previously performed work for our own department, or performed work on a Federal-aid project in another state, is limited to 100,000 square yards of concrete pavement or 200,000 cubic yards of grading.

Contractors who have satisfactorily performed work on Federal-aid projects in other states are qualified for work of similar character and amount subject, of course, to the provision that they present statements showing adequate finances and equipment. Contractors who have previously performed work for the Minnesota Highway Department are qualified for whatever amount of work we judge them capable of handling. Statements on standard forms are required at least once each year, and more frequently when deemed advisable.

How the Various States Handle the Matter.—At the time I was requested to prepare this paper I wrote to all the Highway Departments asking for their experience in this particular phase of work. I have received replies from practically all of them and have attempted to set forth as briefly as possible the more important features of the rules which are in effect in each state. These are as follows:

Alabama.—The Highway Department of this state requires that contractors who wish to bid on work place on file with the department every six months the information required by the standard questionnaire.

Arizona.—The Arizona State Highway Department prequalifies contractors and limits the bidding.

Arkansas.—Requires that contractors submit statements covering experience, equipment and finances, but does not make the determination until after bids have been received.

California.—Contractors desiring prequalification are required to fill out and submit to them the standard forms. If a prequalification in excess of \$50,000 is desired the financial statement must be certified to by a certified public accountant. New statements are required not less than once each year.

Colorado.—Have been qualifying contractors for the past three or four years. Require statements on standard forms.

Connecticut.—The laws of Connecticut do not permit the Commissioner of Highways to require prequalification, but they do require that the contractors file with the

department statements covering finances, experience and equipment. These are used in determining the ability of a contractor after bids have been received. Financial statements may be required two or three times in any one year, according to the department's estimate as to the financial ability of any particular contractor.

Delaware.—Prequalification in this state has been used only on certain bridge jobs of unusual size or expense. It has not been used on paving or grading.

Georgia.—Prequalification has been in effect for four years. It is the statement of the department that they have not had a single failure during construction since prequalification has been in effect, and only one case where the bonding company was required to assist in completion of the work. They require filing of forms which vary somewhat from the standard, but are in many respects similar. These must be filed not less than 30 days in advance of the time the proposals are submitted.

Idaho.—This state is acting under a Public Works Contractors' License Law, which substantially amounts to prequalification as a contractor in order to receive a license must submit statements very similar to those employed in prequalification. The license must be issued not less than 30 days before a proposal can be submitted on any public work. This method has worked out very much to the satisfaction of the Highway Department of that state.

Iowa.—The first qualification rules were put in effect in 1926 and the first restriction was to the effect that contractors who had not previously constructed paving work under the commission's supervision could not bid on projects involving more than approximately 12 miles of pavement. This was later reduced to 8 miles and remained at that point until the Bureau of Public Roads issued their memorandum in May, 1932. They require that the financial statement be certified to by a certified public accountant.

Illinois.—Contractors are required to submit statements twice each year, on June 30 and December 31. The financial reports are analyzed by the Bureau of Audits in order to determine the net amount of working capital. The amount of net working capital represents 15 per cent of the amount of the contract the division will award to a contractor and this represents the contractor's qualification. Statements are on forms which, in general, correspond to the standard.

Indiana.—Indiana does not prequalify contractors, but does require that all contractors bidding file a financial statement with their proposal. In case the low bidder's financial statement is not satisfactory he will not be awarded contract.

Kansas.—Prequalification has been in effect in this state for the last four years and found to be very satisfactory. In the set-up of this state, detailed information is issued to certified public accountants as to the exact manner in which the financial statement must be prepared and the comparison which must be made between the various accounts kept by the contractor.

Louisiana.—Does not require prequalification, but does require that all contractors submit with their proposals statement covering finances and experience. These statements are on the standard forms.

Maine.—Have not as yet put into effect provision for prequalification, but expect to do so. Chapter 159 of the Public Laws of Maine, 1931, authorizes prequalification of bidders. They do require a statement covering finances and equipment to be submitted with the proposal for consideration before any award of contract is made.

Maryland.—Prequalification has been in effect for some years. Standard statements are required and must be filed at least once a year, and more often if desired.

There is no law authorizing prequalification and the matter has been handled in a manner judged to be most practical by the commission.

Massachusetts.—Does not employ prequalification, but determines the ability of the contractor after the proposals have been received.

Michigan.—Prequalification was authorized by a law passed in 1933, effective July 1 of that year. Under this law no one can submit a proposal who has not previously filed with the department the required forms, giving statements relative to finances, experience and equipment. The contractor must have liquid assets not less than 20 per cent of the maximum rating. The maximum rating is determined by a method similar to that used by Wisconsin. In order to provide for wider distribution of work the present maximum rating is \$250,000.

Minnesota.—Has qualified contractors for four years and requires statements on standard forms. Does not require financial statement by a certified public accountant, but expects to do so in the near future. First contracts, other than those governed by the Bureau of Public Roads limitation, are 100,000 square yards of pavement or 200,000 cubic yards of grading. Under ordinary circumstances assume maximum rating four times the quick assets, providing contractor does not have to purchase additional equipment for the class of work he is qualified to bid upon. The maximum rating on other than first contracts is determined solely on basis of finances, equipment, organization and ability to perform work. This latter requisite is used primarily with contractors who have previously performed work for the department. We find that there is often a material difference in the ability of contractors to perform work, even though their financial condition and the amount of equipment they own are comparable.

Mississippi.—Adopted prequalification from and after November 1, 1933, required statement on standard forms. Have not as yet had sufficient experience to venture any opinion as to its merits.

Missouri.—Have been prequalifying contractors for the past one and one-half years. Contractors are required to submit financial statement, prepared by a certified public accountant, on June 30 and December 31. This statement must be submitted not less than seven days in advance of date upon which bids are to be received. Financial statement is checked by the Auditing Department and final qualification passed on by the Rating Committee, which consists of the Chief Engineer, Chief Auditor and Construction Engineer.

Montana.—Have been prequalifying contractors for the past four years and their experience has been very satisfactory. Require statements once each year on or about January 1. They keep a record of all qualified contractors, together with maximum total value of work which they believe each firm competent to handle and make awards up to that total amount.

Nebraska.—Does not require prequalification, but does require standard statements, to be taken into consideration prior to award of contract.

Nevada.—Contractors in this state are required to do work under a license law, and no contractor can construct public works in that state until he has received a license. There is also a law which requires that the State Highway Engineer must secure contractors' statements before issuing to them the plans and specifications for any highway projects. The financial statements required are very similar in form to the standard.

New Hampshire.—This state replies that they have not found it necessary or advisable to adopt this practice, and up to the present time no attempt has been made to

determine responsibility of bidders until after receipt of proposals.

New Jersey.—Have been qualifying contractors since January, 1932, and have found it to be very satisfactory. Procedure is according to the standard forms.

New Mexico.—Have been prequalifying contractors for several years and have recently issued memorandum to the effect that financial statements must be prepared by certified public accountants. Their experience has been entirely satisfactory.

New York.—Does not require prequalification or submittal of financial statements with the proposals. Competency of the bidder determined after bids have been received.

North Carolina.—Have been requiring prequalification for a number of years and found it to be very satisfactory. The information is required on standard forms.

North Dakota.—Have been prequalifying contractors for past several years and found it to be very satisfactory. Statements are submitted on the standard forms and are required to be filed in January of each year and more often if required.

Ohio.—The law of Ohio, known as House Bill No. 281, was put into effect January 19, 1934. This will work out in a general way in conformity with the prequalification rules under force in other states, except that this, of course, has the advantage of being specifically authorized by an act of the Legislature and there can be no question as to its legality.

Oklahoma.—Does not require prequalification of contractors but requires financial and experience statements.

Oregon.—Prequalification law became effective in this state on January 6, 1931, and made it unlawful for a public office to issue proposal forms for public improvements, in case the estimated cost exceeded \$10,000, to any one who had not previously submitted financial, equipment and experience statements. The forms on which these statements are to be submitted are, in general, similar to the standard form.

Pennsylvania.—Does not require qualification since their Attorney General has advised them that it could not be enforced without legislation. They do require qualification statements to be submitted with the proposal and have found that this works out fairly satisfactory, as they are able to determine to their own satisfaction the rating which individual contractors or firms should be given.

Rhode Island.—Does not require prequalification as most of the contractors bidding on their work are people who have worked with them in the past, and whose abilities are fairly well known.

South Carolina.—Require prequalification and use the customary forms in arriving at the value of the work which might be awarded to any contractor.

South Dakota.—Does not employ prequalification in the usual sense, in that statements are required to be filed prior to receiving of bids and are considered at making of the award. The forms upon which statements are submitted are according to the standard.

Tennessee.—The Commissioner of Highways, by an act of the Legislature, was empowered to make such rules and regulations as necessary. The ratings are made on reports received from contractors on forms which, in a general way, correspond to the standard.

Texas.—This state requires prequalification of contractors and that the information be submitted to them on the usual forms. The financial statement must be audited and certified to by a certified public accountant.

Utah.—This state is operating under a contractor's license law, and since financial responsibility and experience are necessary in order to obtain a license, it has

never been found necessary to prequalify contractors in any other respect than to determine whether or not they have been properly licensed by the state.

Vermont.—Does not require prequalification, but requires a statement covering finances, equipment and experience which must be submitted with the proposal. The department determines from the statement whether or not he is competent to perform the work should he be the low bidder.

Virginia.—This state is required by court ruling to permit any one so desiring to submit proposal on the work, and the contractor is a qualified bidder as long as he can obtain a bond. The commission, under the law, can reject any and all bids for reasons other than financial.

Washington.—This state does not prequalify, but requires the low bidder to furnish information as to finances, experience and equipment before the award will be made.

West Virginia.—Does not require prequalification, but requires that a contractor file with his proposal questionnaire giving statement covering experience, finances and equipment.

Wisconsin.—As stated earlier in this discussion, I believe that Wisconsin was one of the first states to enter into the practice of prequalifying contractors. On account of their wide experience I believe it would be advisable to give somewhat more special attention to their system than has been given to the other states. The first requirements for prequalification were put into effect in 1926 and these regulations have been made more rigid from year to year. Their experience during the period in which these rules have been in effect has been very satisfactory and the number of defaults and failures has been reduced very materially.

The work is divided up into various classifications, depending upon the character, and the contractors are qualified for various kinds of work in varying amounts, according to their experience, finances and equipment. Ratings are determined on the following basis:

General ability of prospective bidder.....	10
Construction experience of prospective bidder.....	10
Contractors relation of prospective bidder with State Highway Department on previously completed work:	
A. Efficiency shown in executing previous contracts.	10
B. Attitude toward department and its regulations...	10
C. Attitude toward general public in vicinity of work	10
D. Attitude toward labor employed.....	10
E. Record as to unpaid accounts and claims.....	10
F. Equipment and credit.....	30

If a contractor can make a perfect showing in all of these items he will be given qualification having a maximum capacity rating, after showing sufficient liquid capital. Otherwise the maximum rating will be reduced by whatever amount he fails to meet these requirements. Financial statements and experience questionnaires must be submitted at least once each year and as often as may be required by the commission. In case a contractor is rated for doing several different kinds of work under various classifications, these classifications are not accumulative or transferable. He can not exceed his classification in any particular kind of work.

I believe that Wisconsin is possibly the only state which publishes a list giving names and addresses of all contractors doing work for the commission, together with their rating for each and every kind of work that they may be qualified for.

It is my understanding, both from personal observation and from contact with the Wisconsin Highway Commission and its officials, that they have been very

well pleased with the manner in which this has worked out in that state. I believe that the officials of the commission are to be commended for the attitude they have always taken in respect to prequalification as, in my opinion, its widespread use throughout the United States is in no small part due to the showing made by the officials of the Wisconsin Highway Commission.

Wyoming.—Prequalification has been in effect for two years and has been found to be very satisfactory. Statements are required on standard forms.

A summary of the replies which have been received from 46 states, other than Minnesota, indicates that out of these 47 states 30 have prequalification requirements. Thirteen states require that the contractors submit their financial, equipment and experience statements on the usual forms, but do not limit the giving out of proposals. In other words, they do not prequalify, but do use the information contained in these statements as basis for award of contract after the bids have been received. Twelve of the states require that the financial statement be made by a certified public accountant. Two states have maximums which they place upon the size of contract which may be awarded to any single contractor, regardless of his financial condition, experience or organization. Several states have limitations beyond which a contractor can not go until he has performed a certain amount of work within their state.

Taken on the whole, the sentiment expressed by the engineers of the various departments was to the effect that they are very well pleased with the results obtained by prequalifying bidders. In almost every case prequalification has resulted in securing a better grade of contractors. The work has been performed more satisfactorily and with less difficulty to the engineer, and there have been fewer defaults and failures on part of the contractors. When we consider the relatively short time in which this method of qualifying contractors has been in effect, and note the large number of states which have adopted its use in some form, it is apparent that it will be only a short time until some method similar in form to this will be required of every contractor who desires to bid upon any form of public work.

Acknowledgment.—The foregoing is a paper presented at the last annual conference of State Highway Officials of Mississippi Valley.

Wis. Policies for Roadside Development

The Wisconsin Highway Commission has adopted the following fundamental policies for carrying out roadside development work:

1. Confine planting to roads on permanent locations.
2. Preserve existing trees and plants.
3. Fit the highway into the surrounding landscape.
4. Minimum right-of-way 100 ft., and 120 or 200 ft. where low prices make this advisable.
5. The highway organization maintains trees and shrubs on right-of-way.
6. Plant in masses rather than in rows.
7. Open scenic vistas.
8. Plant triangles, intersections and strips along the highways.
9. Sod or plant slopes of cuts and fills.
10. Replace snow fences with evergreen snow hedges.
11. Except for some evergreens for snow hedges, acquire stock for planting from commercial nurseries.
12. Ask county boards to donate to the state 150 ft. of any tax delinquent or other county owned land along state trunk highways.
13. Encourage donation of roadside parks to the state.

COUNTY AND TOWNSHIP ROADS

A Section Devoted to Those Interested



In Secondary Road Improvement

Types of Low Cost Bituminous Highway Construction In Missouri

By C. P. OWENS

*Engineer of Maintenance,
Missouri State Highway Department*

IN order to limit the discussion and to more clearly define our topic, this paper will be restricted to bituminous types costing not more than \$6,000 per mile for a 2-in. thickness and a 20-ft. width. It would seem logical that bituminous surfaces costing more than \$6,000 per mile should not be classified as low cost roads but as high type bituminous pavements. Needless to say, such pavements should be comparable with the standard types of bituminous pavements in quality, and capable of rendering a service proportionate to their cost of construction and maintenance.

Five General Types of Missouri.—This paper will necessarily be confined to the types constructed in Missouri since our experience has been limited to work done in that state. In Missouri the construction of low cost bituminous roads has been confined to five general types as follows:

1. *Oiled Earth.*—Costing from \$500 to \$700 per mile.
2. *Blotter Treatment.*—Costing from \$1,000 to \$1,500 per mile.
3. *Oil Gravel Mats.*—Costing from \$1,000 to \$2,500 per mile.
4. *Tar Road Mixes.*—Costing from \$2,000 to \$3,500 per mile.
5. *Crushed Stone Retread.*—Costing from \$4,000 to \$6,000 per mile.

1. The *Oiled Earth Road* is built by applying road oil to a thoroughly compacted dirt road. Usually 1 gal. of oil per square yard is used. It is good practice to apply the oil in three applications of 4/10, 3/10 and 3/10 gal. each, allowing sufficient time for each application to penetrate before applying the next. Oil of 150 to 250 Furol viscosity at 122° F. is commonly used. Routine maintenance consists of patching small holes with stock-pile mixture of oil and earth. Subsequent treatments are made each year at the rate of from 3/10 to 5/10 gal. per square yard after reshaping the road surface with discs, scarifiers, blades and drags or rollers.

2. The *Blotter Treatment* is quite similar to the process of oiling an earth road except that from 1 1/4 to 1 1/2 gal. of oil per square yard are used, followed by a covering of stone chips, coarse sand or fine gravel at the rate of 250 to 300 cu. yd. per mile. It is usually advisable to use an oil of heavier viscosity in the blotter treatment type.

3. *Oil Gravel Mats* are built by thoroughly mixing road oil with well graded gravel or crushed stone aggregate. Usually from 325 to 500 cu. yd. of aggregate per mile are used, resulting in a compacted thickness ranging from 1 in. to 1 1/2 in. In some of the western states the aggregates are extremely fine as compared to the aggregate most commonly used in Missouri. In Missouri we use aggregate ranging downward from the 1 1/4 in. size. Since the method of construction in Missouri probably differs from many of the states a more complete description of the Missouri type of oiled gravel mat will be presented later in the discussion.

4. *Tar Road Mixes* have been built on several projects. Tar road mixes are usually built to a thickness of about 2 in. by mixing about 200 lb. of prepared gravel with from 1.4 to 1.6 gal. of tar per square yard. For primer, tars with viscosity ranging from 16 to 28 are used at the rate of 1/4 gal. per square yard. For mixing with aggregate, tars with viscosity ranging from 60 to 85, or even heavier, are used. After mixing and leveling the material is rolled.

5. *Crushed Stone Retread* should require but little explanation since this type has been described from time to time. Retreads are usually built by road-mixing clean stone graded from 2 to 3/4 in. in size with a heavy grade of cutback, or tar. Surface voids are filled with 3/4 in. chips, which is followed by an application of cutback or tar. Successive applications of stone or chips and bituminous binder are carefully leveled and rolled. Tar is usually used to prime the base. The stone is applied at the rate of 175 to 185 lb. per square yard and mixed with from 1.1 to 1.2 gal. of bituminous material per square yard. The cost of this type ranges in the upper limit of low cost bituminous surfaces, but if constructed properly over a good base it will render many years of satisfactory service at a low maintenance cost.

Development of Oil Gravel Mats in Missouri.—The development of oil gravel mats in Missouri is interesting history. It began with an effort to solve the dust prob-

lem on heavily traveled graveled roads and on gravel roads through towns and villages. Other methods of solving the dust problem had not been entirely successful, so it was decided to try the use of a light road oil, preferably one with but little or no asphalt content. The object was to kill the dust without binding the surface. Light application of 3/10 to 4/10 gal. per square yard were made at intervals through the summer season. Every effort was made to prevent the formation of a mat. If a mat did form, blades were used to cut it loose, or clean gravel was floated over the surface to absorb the surplus oil and to serve as an abrasive to cut the mat loose. In spite of such precautions the gravel and oil formed into mats anyway.

The following year we decided to build an oil mat by using a heavier oil with an asphalt content ranging from 60 to 70 per cent. This oil was mixed with gravel spread at the rate of about 325 yd. per mile, which is sufficient to build a mat 1 in. thick. No special attention was then paid to the gradation of the aggregate, but in practically every case we obtained quite satisfactory results.

The following year we launched into an extensive program of about 800 miles. This program was larger than we desired, but once the demand for such steps started, it was difficult to control. Information on the subject available from other states dealt largely with fine aggregates ranging from 5/8 in. down, whereas our aggregates range from 1 1/4 in. down. Consequently, we were forced to experiment as we carried on a rather large program. We contracted the oil and its application but used our own equipment to prepare the road bed and to process and mix the oil and aggregates. Consequently, we were able to change the methods from time to time as the occasion demanded.

On some of the roads there was sufficient loose aggregate in place to construct a 1 in. mat. On most of the mileage, however, it was necessary to add new gravel to bring the requirements up to 325 cu. yd. per mile. However, the quantity of loose aggregate on the surface varied widely from station to station. The material that was used in place had been on the road surface several years under traffic and subject to abrasion and wear, and contained considerable fines. Where new material was added, a still different gradation prevailed. The new gravel was produced from local sources which threw still another variable into the gradation of the aggregates used. Therefore, the first year's program

of consequence included the use of aggregates with a wide range in gradation even within a single mile.

Before the working season was over, it was necessary to solve and overcome many problems. However, our first year's work, spotted with failures, only a few really serious, was looked upon as successful as a whole. During the following fall and winter our Bureau of Tests and Research watched and checked results carefully, with the result that the following spring we came out with more clearly defined specifications covering road oil, construction procedure, and especially the gradation of aggregates to be used.

Present Specifications.—Our present specifications for bituminous mat surface call for a road oil-aggregate mixture, which, after compaction, is 1 1/4 in. to 1 1/2 in. thick.

The aggregates used are crushed limestone, crushed gravel, limestone chat, sand-gravel, mine tailing chat, jig sand, or any combination of these, graded to meet the following requirements:

	Min. Per Cent	Max. Per Cent
Passing 1 1/4 in. round.....	100	
Passing 1 in. round.....	95	
Passing 1/2 in. round.....	60	85
Passing 3/4 in. round.....	45	65
Passing No. 20 sieve.....	15	40
Passing No. 50 sieve.....	8	
Passing No. 200 sieve.....	2	10

The basis for these gradation limits is purely empirical, resulting from our study of a wide range of gradings used on previous construction. This study indicated that gradations within this range, used with the proper quantity of oil, gave a stable mat with a non-skid surface texture. Mats with coarser gradations were very "open" and had a tendency to pit and ravel; and mats with finer gradations had a tendency to rut and corrugate, particularly if they had been mixed with an excess of oil, or if water got into the mat. No attempt is made to grade aggregates for maximum density on our projects, the principal purpose of the gradation limits being to eliminate highly unstable gradings.

Our experience during the past year, when approximately 400 miles were constructed, indicates that the grading specification is satisfactory; and further, that material of reasonable cost is readily available. The only change contemplated is an increase in the minimum passing the No. 200 sieve to 4 per cent, to permit the use of very slow-curing uncracked oils.

The road-oils used are asphaltic residual oils of the slow-curing type and would meet the Asphalt Institute specifications for SC 2, SC 3, and SC 4 oils, although different tests are used in our specifications. Either cracked or uncracked oils will meet the specifications. Unlike some of the states, our service results to date and the economics involved in the purchase of oils do not permit us to discriminate between these two types of oil.

Construction Procedure Simple.—Construction procedure is relatively simple. During the fall and winter prior to building an oil mat on a road, the maintenance forces clean the ditches, reshape the surface, and work additional metal into areas which have been found to be unstable.

The contractor's first step is to blade the loose road metal into a windrow on one side of the road, estimate the quantity present, and add sufficient new material to bring the total to 500 cu. yd. per mile. The windrow is then "evened" so that it is uniform at all points.

The base is next swept with a mechanical sweeper in order to get all the fines into the mix and to prepare the

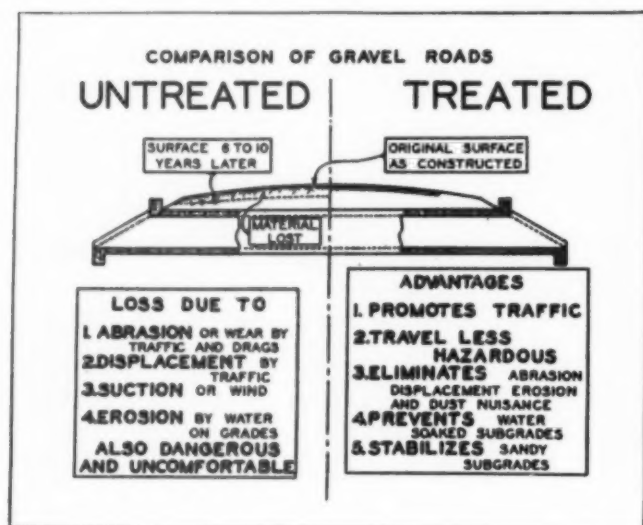


Fig. 1.—Comparison of Untreated and Treated Gravel Roads

surface for priming. A prime coat of either tar or road oil of 200 Furol viscosity at 122° F. is applied at the rate of .15 to .30 gal. per square yard.

After the prime coat has cured and hardened, the aggregate and oil are mixed by either the road-mix or traveling-machine-mixed method.

In the road-mix method the aggregate windrow is flattened to a width of 12 ft. and the oil applied at a predetermined rate by pressure distributor. The materials are immediately mixed with spring-tooth harrows and blade graders or multiple blade maintainers.

In the traveling-machine-mix method, the machine picks the aggregate up out of the windrow, feeds it at a uniform rate, which is synchronized with the oil flow, into a pug mill where the oil is introduced; mixes it, and lays the mixed material back on the base in a uniform windrow. The machine has certain, as yet unevaluated, advantages over the road-mix, principal of which are: better and more uniform proportioning of oil and aggregate; no mixing on, with consequent disturbance of, the primed base; very little inconvenience to traffic during the mixing operation; and a 20 to 24 hour working day.

Subsequent to mixing by either method, the mixture is windrowed adjacent to and on one side of the centerline of the road, and a "tack coat" of .15 gal. per square yard of the same oil used in the mix applied to one-half the road. Half the windrow is immediately spread thinly over this with blade graders in such a manner that a small windrow is formed, outer edge of which coincides with the edge of the finished surface. The other half of the road is treated similarly and final spreading and finishing proceeds, using only motor patrols, and blading the material from the edge toward the center. The effect of this method of finishing is to keep any areas of segregated coarse material in the center of the road where they are more easily compacted than if they were along the edges.

The surface is immediately rolled with a 3 to 5-ton roller, not with the idea of obtaining complete compaction but merely to start compaction and encourage traffic to use the entire roadway immediately, instead of concentrating in two lanes.

In drawing these specifications every effort has been made to avoid refinements which would add to the cost, unless a very definite improvement in service results can

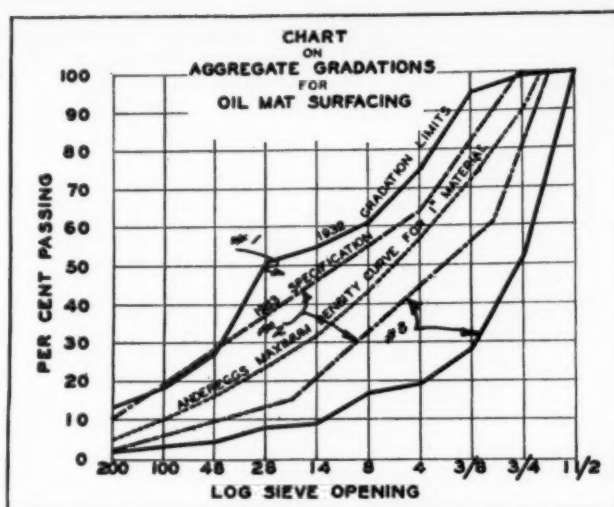


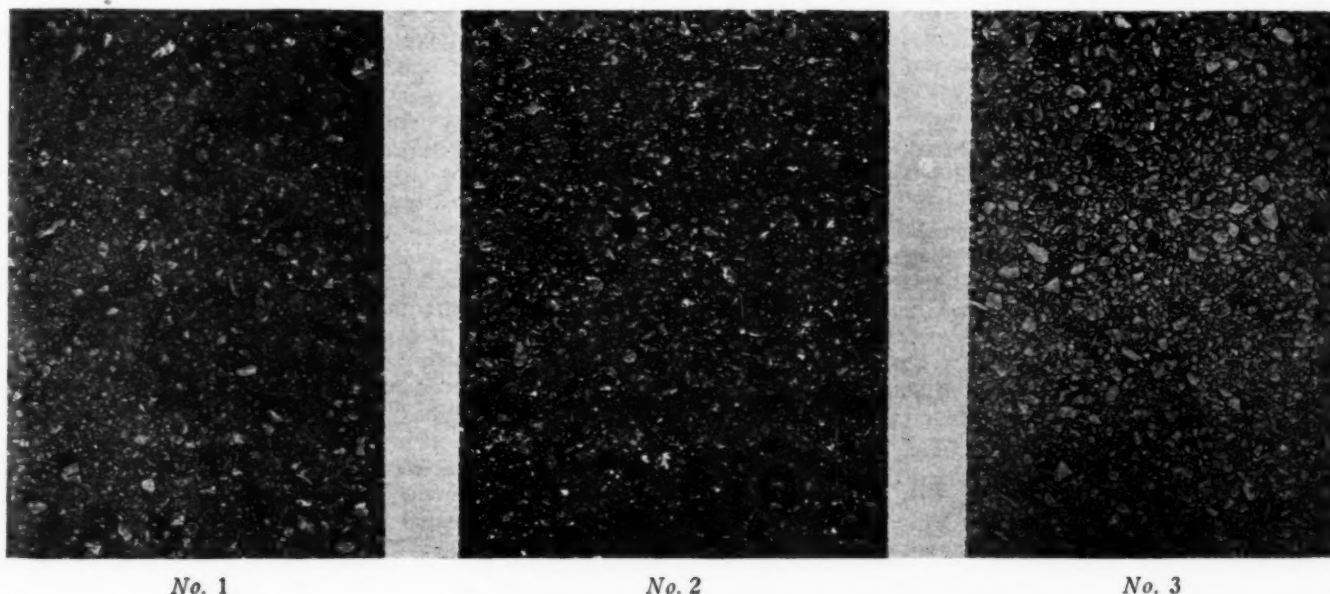
Fig. 2.—Relative Gradations Used During 1932 and Specifications for Materials Used in 1933. Numbers on Curves Refer to Illustrations in Fig. 3

be obtained. To some of the states our specifications may seem crude. On the other hand we feel that some states specify refinements in aggregate grading, bituminous binder and its proportioning, and some phases of construction procedure, benefits of which are not justified by the expense.

As originally conceived, low cost bituminous road surfaces probably competed with high type pavements in too many cases. Ill advised promoters, over-enthusiastic experimenters and highway officials, faced with pressing demands for a large mileage of improved surfaces, are responsible for the construction of roads of this type where pavements undoubtedly should have been built. Errors of this kind have been expensive in some cases and have resulted in condemnation of the low cost type of construction.

However, as we continue to improve the construction methods and to study the type, we are beginning to place the lost cost road in its proper field with more gratifying results.

Low Cost Roads Widely Distributed.—In checking over the state highway map of Missouri, we find low cost bituminous road surfaces widely distributed. We



No. 1

No. 2

No. 3

Fig. 3—Three Typical Surface Textures Showing Range in Sizes on "Chart on Aggregate Gradations," Fig. 2. Numbers Under Pictures Correspond to Numbers on Chart. No. 2 Is Considered Ideal Gradation and Surface Texture of Newly Finished Surface. No. 3 Is Too Coarse—Lacks Intermediate Sizes and Fines.

have used oil earth and gravel mats throughout the agricultural section of the state where the fertile black soils prevail. In the south central or Ozark portion of the state, the gravel subsoil makes conditions ideal for successful surfaces of retread, oil mats and tar mixes. In the flat area of Southeast Missouri we have used oil successfully to stabilize the sandy subsoils, as well as to build oil gravel mats.

During the years of 1928, 1929, 1930 and 1931 our primary program was nearing completion but many of our pavements were disconnected. The value of the pavements were made available at an early date for through traffic by oiling the earth gap. Some of these oiled gaps served traffic for a period of four or five years.

We have also built a considerable mileage of 9-ft. and 10-ft. concrete slabs with a view of increasing to full 20-ft. width at a later date. We found it necessary to use road oil to prevent erosion on the other half of the roadway, and to provide a surface for the increasing traffic. Road oil on well graded compacted earth not only solved this temporary problem, but proved so economical and successful that we have since used road oil to eliminate mud and dust on light traveled farm-to-market and secondary roads in sections where gravel and crushed stone are expensive.

Where we anticipate a longer use of road oil as a surfacing material, we have added a covering of coarse sand, gravel or stone chips to form the blotter treatment. This covering material thickens and toughens the mat, which will render better service. The blotter treatment type is used where we desire longer service without re-treatment, or have a heavier volume of traffic to carry.

In the construction of a new road, highway engineers are often at loss to predict the volume and character of traffic the road will carry. Usually the local people are optimistic as to the volume of traffic the new road will carry, while the engineer may be pessimistic. In such cases a blotter treatment or oiled earth type may be used for a few years until a check on traffic can be made. If the expected traffic does not develop, the engineer has conserved funds that can always be used elsewhere. If traffic does develop to justify paving, the expense of oiling is justified in the knowledge gained while the fills are settling and grade is being stabilized.

Oil-Gravel Mats.—Oil-gravel mats are generally built where traffic is seasonal, or the road is secondary and carries limited heavy traffic, but may carry unlimited light traffic. In most cases such roads do not carry a sufficient volume of traffic to justify the expense of paving. Usually considerable money is already invested in a gravel surface that is not old enough to have its cost amortized. Under such circumstances an oil-gravel mat surface may prove to be true economy.

It is difficult to predetermine the strength of an old gravel or stone base. Slight movements under loads during thawing or wet season are likely to be unobserved on a well maintained gravel road. These movements are likely to become quite noticeable after the bituminous surface is built. Consequently, the type of construction first used should be not only low in cost but also should be easy to reconstruct, easy to repair and easy to add to in thickness if necessary. Where such conditions prevail the oil gravel mat type seems to fit in ideally.

Oil gravel mats as built in Missouri are easily reconstructed and have a high salvage value. As a general rule base failures are confined to small isolated places or to particular portions of a project. Areas broken up through base failures are repaired by scarifying and blading the loose mixture to one side; and after drying out and stabilizing the base, the mixture is then respread

and left to be compacted by traffic. Usually it is necessary to reprime the base or add a slight amount of oil to the mixture. Thus oil gravel mats are well adapted to sections where there is some question as to the stability of the base.

We have in Missouri a large mileage of oil gravel mats only 1 in. thick. However, during the past year all our oil mats have been constructed to a thickness of $1\frac{1}{2}$ in., which seems to be entirely adequate. Funds conserved in building the minimum thickness may be used to repair the base failures or to add strength and thickness to portions that may fail. Also, in Missouri there is a marked tendency for any road surface, including slabs, to lose its true cross-section and profile under the pounding of traffic and the action of climatic changes. Therefore, it seems logical to conserve funds by building the required minimum thickness and to use the money so conserved at a later date to add extra thickness where necessary to obtain greater strength or to improve the cross-section and profile, or both.

The crushed stone retread type should be used only where the base is adequate since repairs are more expensive on this type. The retread type has better stability than the oil mat and when built over a good base is capable of carrying fairly heavy traffic for several years without further major attention. It has the advantage of being constructed to exact formula that produces uniform results. It is contemplated that whenever our present oil mats need resurfacing, the retread type, calling for a better grade of bituminous materials and a more carefully prepared aggregate, will be the type selected in most instances.

The problem of the selection and the construction of low cost bituminous surfaces and their place in the state highway system is not entirely solved. To keep these types in the low cost field, it is necessary to use available local materials obtainable at low cost. Therefore, their construction cannot be an exact science. There is the question of gradation of aggregates and how far the engineer should go in expense to obtain the ideal. There is the selection of bituminous materials ranging from straight run or cracked residuals to the refined cutbacks with special run solvents. The engineer can go on and on with these refinements, each time adding some costs until he builds a low cost road surface that is low cost in name only.

To justify its place in the highway program, the bituminous surface must remain in the low cost field in fact and not in name only. Elaborate methods and expensive procedures must be avoided, especially when the benefits are not necessary or are not justified by the expense. On the other hand, the construction should not be haphazard or careless. Care and skill may be used without involving expensive methods. The construction of low cost bituminous pavements does not justify frills.

In every state highway system, there is and probably always will be a large mileage of roads carrying a volume and type of traffic that does not justify a high type paved surface, yet which demands and justifies something better than the inconvenient, expensive to maintain, traffic bound or gravel type. It is this intermediate class of highways that creates a large field for the low cost bituminous road surface. Therefore, we as highway officials and engineers will continue to devote our efforts and time to the further development and study of methods of building and maintaining low cost bituminous road surfaces.

Acknowledgment.—The foregoing is an abstract of a paper presented at the last annual conference of the State Highway Officials of the Mississippi Valley.

EDITORIALS

Gasoline Tax Abuses

"Since it is unfair and unjust to tax motor vehicle transportation unless the proceeds of such taxation are applied to the construction, improvement, or maintenance of highways, after June 30, 1935, federal aid for highway construction shall be extend only to those States that use at least the amounts now provided by law for such purposes in each State from State motor vehicle registration fees, licenses, gasoline taxes, and other special taxes on motor vehicle owners and operators of all kinds for the construction, improvement, and maintenance of highways and administrative expenses in connection therewith, including the retirement of bonds for the payment of which such revenues have been pledged . . ."

THE above quotation from Section 12 of the Hayden-Cartwright Road Act (signed by the President on June 18) expresses definitely and bluntly the feeling of our national legislators on a point long sore with the motor industry and the motoring public. Nor is the statement regarding fairness and justice weakened by the proviso at the end of the section to the effect that these provisions shall not operate to deprive any State of more than one-third of what it would receive under the other sections of the act: the reduction of the penalty is merely an expedient, a concession typical of tax legislation.

The avowed purpose of the gasoline tax is, and always has been, to provide for road construction and expenses. Though excessive when compared with property taxes or other sales taxes (in some cases the tax forms one-third of the total retail price of gasoline) it has received comparatively little opposition from motorists because of the belief that the money was to be spent in their interest. Had they reason to think otherwise, there would have been storms which even the hardest legislators would not wish to face.

But little by little the diversions have crept in, until in 1933 a total of \$55,742,173 of State gasoline tax money was appropriated for other than highway purposes—a huge amount in dollars and a not inconsiderable percentage of the \$519,403,450 total gasoline tax assessed by the forty-eight States and the District of Columbia. Diversions of State license fees and of various assessments made by cities will add millions more to the total paid by motorists for purposes in which they have no special concern.

The figures here used are from a table in the July issue of "Public Roads" (a journal of highway research published by the U. S. Department of Agriculture) in which further details are given by States. Totals for all States and the District of Columbia are as follows—(The federal tax is not included):

	Year 1933
Net tax earning on motor vehicle fuel (after deduction of refunds allowed by law).....	\$518,195,712
Other receipts under tax law (licenses, etc.).....	1,207,738
Grand total earning (tax and other receipts).....	\$519,403,450

Disposition of grand total earnings according to law:

Collection and administration cost.....	\$ 2,727,801
Construction and maintenance on rural roads:	
State highways	277,517,371
Local roads	111,109,158
State and county road bond payments.....	58,972,767
On city streets.....	13,334,180
Other than highway purposes.....	55,742,173

Total\$519,403,450

Note that in the above items, the amount for city streets is less than one-fourth of what was taken for other than highway purposes. And yet many of us who drive in both country and city find the chief source of car damage to lie in the worn out and broken down pavements within corporate limits.

A glance at the details of these diversions is instructive. As might be expected, emergency relief dominates, its total being \$28,391,702, or slightly more than one-half of the total diversion. Public schools received \$12,969,347. \$7,842,768 was indicated as going to State general revenue, State general fund, or State treasury. \$6,011,248 went for various purposes including port and harbor construction, conservation, aeronautics, warrant redemption, payments on rural credit bonds, and payments on emergency relief bonds, the last named being entirely in a single item of \$869,057. Of the entire lot, only \$527,108 was for purposes of primary concern to motorists—gasoline inspection, police patrol and enforcement of motor vehicle laws.

Twenty-six of the forty-nine taxing bodies made no diversions in 1933. More power to them. Diversions by the others ranged from \$12,735 to \$14,404,277, which latter was 33 per cent of the total gasoline tax imposed by the State. It should be noted however that this item is listed as "State emergency relief fund from one cent extra tax," so that the purpose of the tax should have been clearly undersood from the beginning.

Seven States, in all, appropriated gasoline taxes for relief or charity. How far such appropriations are to be condemned must depend on the circumstances in each case, for in times of great stress drastic expedients may be necessary. Some may have been wholly justified—others not at all. But of the major diversions other than for relief there can be no question.

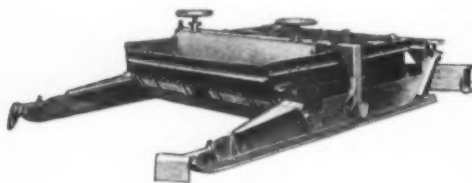
The motor vehicle owner pays a property tax on his truck or car; he pays the same income, sales, and miscellaneous taxes as other citizens; in the manufacturers' excise tax on motor vehicles, he pays in effect a special luxury tax to the federal government; from the expenditure of all which he benefits as do other citizens—no more. To tax his gasoline for the benefit of general funds or public schools or conservation or rural credits is unjust and intolerable. To tax it for public relief is an expedient to be sanctioned only as a last resort; we suspect that portions of the \$28,000,000 relief fund could have been more equitably assessed. In several States there are court decisions against diversions.

Unjust taxation ultimately reacts. It cost England thirteen good colonies and the French aristocracy their heads. Charges of "what the traffic would bear" (not taxes, to be sure, but a sufficiently close parallel) brought misfortune to American railroads. In the present instance, happily, only political heads will fall, but fall they will if the gasoline abuse continues. The rights of the motor industry and the motoring public cannot be ignored indefinitely.

NEW EQUIPMENT AND MATERIALS

New Spreader Finisher

A screed vibrated at 3,500 r.p.m. for vibratory spreading, striking off and finishing, 15 ft. long "straight-edge" sled runners, which act as forms, equalize high spots and smooth the surface, and a telescoping main frame used in combination with screed extension wings to give 9 to 14 ft. width adjustability—these are some of the fea-



New Jaeger Vibro-Spreader

tures of the Vibro-Spreader which The Jaeger Machine Company has developed for laying secondary roads.

The machine spreads gravel, rock, slurry, armor plate, macadam and hot or cold bituminous mixes—leveling, binder and top course—any width from 9 to 14 ft., any thickness between 1 and 8 in. On 2- and 3-lane work the clean-up or flushing wings insure proper blending of strips and uniform density.



Spreader Finisher on Job

The vibration of the screed, which is also imparted to the sled runners, keeps materials plastic and the load "alive," reducing draw-bar pull and making possible much faster spreading, it is stated. Once over with the Vibro-Screed places rock, Macadam and bituminous mixes, hot or cold, are placed ready for rolling as fast as they can be fed.

In addition to the smoother surface, due to the long sled runners, this increased speed and capacity offer the advantage of real job savings, according to the manufacturer. Bulletin BS-34, issued by The Jaeger Machine Co., Columbus, O., describes the machine in detail.

New Snow Plow Development

A development of great interest to highway officials and other users of snow plows is the Blackhawk hydraulic "lightning blade-lift."

It consists of a reservoir and twin pumps which are located in the cab so that the handle of the pump is within easy reach of the driver's hand. From the illustration, it is apparent that as the operator pumps the cab unit, he forces the oil through the high pressure flexible hose to the ram out in front, thus raising the plow.

To lower, the operator simply opens the release valve, located on the top of the control unit, thus allowing the oil to return to the reservoir.

Incidentally, the drop of the blade is in



Illustration Showing How Blackhawk Hydraulic Blade-Lift Is Operated

instantaneous or controlled at will by the operator.

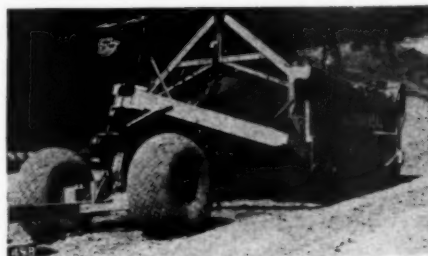
According to the manufacturer, the Blackhawk "lightning blade-lift" offers three distinct advantages over the mechanical winch type of hoist: easy operation, warm cab comfort, and low maintenance cost.

The installation is simple and economical enough so that old plows can be changed over to this up-to-date hydraulic control.

Write the Blackhawk Mfg. Company, Dept. RS7, 120 N. Broadway, Milwaukee, Wis., for further details.

New 12-Yd. Carryall Scraper

The R. G. Le Tourneau Company at Stockton, Calif., announces a new carryall scraper of 12 yd. capacity. This new design embraces all of the features which have made the older model so successful, eliminating, however, all center obstructions through the carrying bowl. The benefits of this feature are immediately apparent. Built as it is, loading can be accomplished by dragline or shovel as well as by



New Le Tourneau 12 yd. Carryall Scraper

the conventional self-loading method. Thus a double purpose unit is given at a small additional cost.

The same high grade alloy steel is used and all electric welded construction is maintained throughout, as in all other models.

The design of the bowl and apron is now claimed to give a great deal freer disposition of material. In sticky gumbo and mud or where rocks are loaded, a larger throat and higher apron opening is stated to assure a free delivery of material.

Another feature which has been given prominence is the use of low pressure tires of large diameter. A drastic change in tire construction by a prominent tire manufacturer has given the Le Tourneau Co. 20-in. air tires suitable for construction work. The weight of the new carrier is 14,050 lb.



New Lightweight Drifter

A new drifter, weighing 126 lb., which can also be equipped with spring handles for use as a sinker, has been announced by the Gardner-Denver Co., Quincy, Ill.

The new D-79 has the "streamline" design, originated by Gardner-Denver, and incorporates a number of desirable features which are stated to result in high speed, low maintenance cost and ease of operation.

Among these features are an automatic valve which gives high speed with low air consumption; special long-wearing bronze



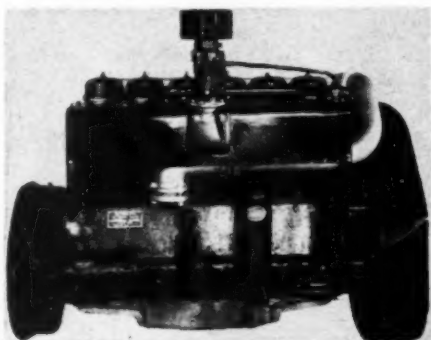
New Lightweight Drifting Drill

removable front cylinder liner; direct center exhaust; rugged throttle valve with out-board bearing; and three-point cross-head support. An integral lubricator supplies lubricant to all parts of the machine, a chamber surrounding the front cylinder bushing being used as a reservoir from which the lubricant is fed to all parts of the drill.

The D-79, it is stated, is remarkably free from vibration, due to its special construction, and is also light in weight for easy handling. This drill is the second of the Gardner-Denver "D" Series drills to be announced.

New Direct Air-Cooled Engine

A new and improved design of the Doman-Marks engine has been announced by the Doman-Marks Engine Co., Amesbury, Mass. An outstanding characteristic of the Doman-Marks engine is the direct air cooling of its cylinders. The cooling air is supplied by a large centrifugal blower mounted on the crankshaft. From this



Oil Cooler Side of Model 6A-377 Engine; 3-Flange Exhaust System, with Inlet Manifold Heater

blower the air is divided into two distinct streams. One stream is directed to the cylinder heads, while the other stream is directed onto the cylinder barrels. This eliminates eddy currents in the ducts and thus improves the cylinder cooling. The blower is of a very efficient design and requires a surprisingly small amount of power to drive it.

Other features of the engine include the following: The individually cast cylinders of chrome-nickel iron are screwed into an aluminum head while at a high temperature, thus making a permanent union. Accessibility of cylinder fastenings makes a valve grinding job as simple as other constructions, while cylinders facilitate repairs and expense. The crankcase is cast iron and exceptionally rigid. Lubricating oil is forced under pressure to all wearing parts, including the piston pin which floats in a bronze bushing in the rod and in bosses of the specially designed aluminum piston. Oil is also forced under pressure to all bearings of the overhead valve parts.

New Centrifugal Compressor

A recent addition to the line of centrifugal compressors and exhausters built by the Roots-Connersville Blower Corp. of Connersville, Ind., is the single-stage Type "OIB" unit. In this design, the machines have their own shafts and bearings and are suitable for direct connection to standard electric motors

or steam turbines, without special shaft extensions. They are also adaptable to V-belt or flat belt drive.

Impellers are furnished in aluminum or carbon steel in the standard construction, but special alloys can be supplied where conditions require. Open-type impellers are used in the smaller sizes, with closed type for larger machines. Each impeller is designed to meet specified requirements.

Casings are ordinarily made of cast iron, but special alloys, to resist corrosive or abrasive action, can be supplied on order.

Type "OIB" units have a sturdy bearing stand that fits them for heavy duty service in a wide variety of industrial applications, according to the manufacturers. Anti-friction bearings are used in smaller sizes, and sleeve bearings in the larger.

Link-Belt Personnel Change

Link-Belt Company announces that Mr. G. H. Burkholder, formerly of Philadelphia, is appointed Western Sales Manager of the Positive Drive Division, with headquarters at the company's Dodge plant in Indianapolis.

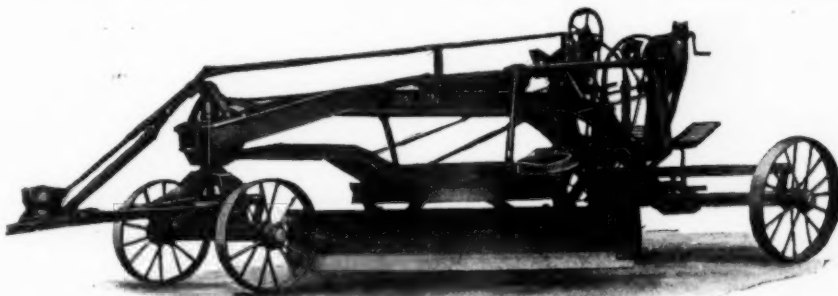
New Galion Grader

A new manually controlled leaning wheel grader embodying many improved features of construction has been placed on the market by the Galion Iron Works & Mfg. Co., Galion, O. The machine weighs approximately 7,300 lbs. and is equipped with a 10-ft. moldboard and blade.

Ease of operation and full visibility of the work were foremost considerations in the design of this new grader. In addition to the usual adjustments such as leaning the wheels, sideshifting the frame, etc., a wider range of blade adjustments are available, making it possible to trim shoulders by extending the blade far out of line of the frame; also for setting the blade at any angle for bank cutting. These special adjustments are made without changing the machine in any manner.

All wheels and blade lifting gear worms are mounted on adjustable Timken taper roller bearings. Moldboard adjustments are controlled by the E-Z lift gearing which operates in an oil-tight case.

Where required, an efficient eleven tooth scarifier with E-Z lift control can be furnished. For ditch forming and trimming low banks a bank sloper with V or flat bottom can be supplied.



Galion 110 E-Z Lift Leaning Wheel Grader

WITH THE MANUFACTURERS

Chicago Pneumatic Tool Acquires Mitchell Diamond Drill

Chicago Pneumatic Tool Company, who for approximately two years has acted as general sales agent for the Mitchell Diamond Drill Company, Ltd., San Francisco, Calif., announces that it has purchased the patents, goodwill and tangible assets of that company and has taken over its personnel. The manufacture of Mitchell Diamond Drills, parts and fittings, as well as "ready-set" bits will be continued at San Francisco for the present. Later the Chicago Pneumatic Tool Company will transfer the manufacturing operations to their plant at Detroit, Mich., where CP Rock Drills and Pneumatic Hammers are made. All the sales and service facilities of the Chicago Pneumatic Tool Company will now be available to the numerous users of Mitchell Diamond Drills.

Salditt Made Export Manager for Harnischfeger

The Harnischfeger Corporation of Milwaukee, Wis., manufacturers of industrial and contractors' equipment, has just an-



Frederick Salditt

nounced the appointment of Frederick Salditt as manager of the export division.

Mr. Salditt brings to his new position a wealth of experience accumulated through

many years with the corporation in shop, offices, service, engineering, sales and foreign departments.

The Harnischfeger Corporation, this year celebrating its 50th anniversary, maintains branches in Europe and representatives in important world markets, as well as offices in the principal distributing centers of the United States.

Chain Belt Appoints New Northern California Distributor

The Chain Belt Co. of Milwaukee, Wis., announces the appointment of the Jenison Machinery Company, 20th and Tennessee Streets, San Francisco, Calif., as a distributor of Rex construction equipment in the northern portion of the state of California.

The Jenison Machinery Co. has been in the construction equipment business for many years. E. S. Jenison, President; T. F. Pimper, Vice-President; H. L. Davis, Secretary, and H. J. Schiefer, Treasurer, are all prominent figures in the construction world on the West Coast. A stock of Rex mixers and pumps is carried in their warehouse, making it possible for them to make delivery in the Northern portion of California quite promptly.

Louis Frederick Nagle of Central Iron & Steel Dies

Louis Frederick Nagle, General Sales Manager of the Central Iron and Steel Company, Harrisburg, Pa., died in that city on August 2 after an illness of one week.

He was born in Pottstown, Pa., March 9, 1868, the son of Henry W. and Barbara Byar Nagle. Following his graduation from the Arms Academy of Pottstown and the National College of Commerce, Philadelphia, he began his business career with the Glasgow Iron Company, Glasgow, Pa., with whom he was associated about ten years. He then joined the Worth Bros. Company organization at Coatsville, Pa., serving as General Sales Manager, and Purchasing Agent for nineteen years.

Upon the absorption of this company by the former Midvale Steel and Ordnance Company, he removed to Pottstown, Pa., and established the Nagle Steel Company, which operated for a period of ten years.

In 1924 he associated with the Central Iron and Steel Company and shortly afterward was made General Sales Manager of that company. He was especially well known in the plate steel industry for his indefatigable energies, devoting all of his time to his various business enterprises.

His orchestral and choral accomplishments made him unusually popular in his church affiliations. In addition to serving for many years as chorister in Coatesville, Pottstown, and Harrisburg, he held the office of deacon in the Baptist congregation.

Knisely Now with Republic Steel Corp.

Stanley A. Knisely, of Cleveland, O., has been appointed advertising and sales promotion manager of Republic Steel Corporation, with headquarters at Youngstown,

O. He succeeds L. S. Hamaker, who was recently made vice president and general manager of the Berger Mfg. Co., Republic subsidiary, of Canton, O.

Knisely entered newspaper work in his home city of Canton, O., and later held the positions of city editor and telegraph editor of the Cleveland Plain Dealer. He left the newspaper field to become advertising and sales manager of the National Paving Brick Association, with headquarters in Cleveland. After six and a half years in this position, Knisely became director of advertising research for the National Association of Flat Rolled Steel Manufacturers and served seven years in this capacity.

E. K. Swigart of Bucyrus-Erie Dies

With deep regret, Bucyrus-Erie Company announces the death of Edmund Kearsley Swigart on July 7th at Ballard Lake, Vilas County, Wisconsin, as the result of a heart attack. Mr. Swigart was born in Bucyrus, O., on April 16, 1867. After his graduation from Toledo High School, he was in the railroad mail service



Edmund Kearsley Swigart

for ten years. He joined Bucyrus-Erie Company in 1891 and was made Secretary and Treasurer of that Company in 1901. As secretary he was responsible for sales, and made many friends among the contractors of those days.

In 1910 Mr. Swigart was made a Joint Managing Director of the Company, and in 1911 was made Senior Vice President, a position which he held until his death.

Mr. Swigart was also a member of the Executive Committee and Board of Directors of Bucyrus-Erie Company, a member of the Board of Directors of Bucyrus-Monaghan Company, Chicago, and Chairman of the Board of Directors of the Oil-gear Company, Milwaukee.

Few men leave behind them a record of achievement such as his. He was held in high regard by all who knew him and his success as a business man, a sportsman and a friend was due to his strong character, pleasing personality, unusual ability to

judge human nature and his sound judgment. His business associates will long cherish the memory of this man, whom they held in such high regard.

Godfrey L. Cabot, Inc., Moves to New and Larger Offices

The general offices of Godfrey L. Cabot, Inc., one of the world's largest manufacturers of carbon black, have been moved from the Old South Building, Boston, where they have been located for more than a quarter of a century, to 77 Franklin St. in that city.

The move to the new quarters, which comprise the top floor of the Columbian National Life Insurance Company Building, was necessitated through need of more space in which to accommodate the personnel of the office, which has been materially increased during the past few years.

The Cabot companies will continue their very complete laboratories at 29 Lincoln St., Boston.

Their carbon black plants are located in Texas, Oklahoma, and Montana. Their natural gas properties are largely centered in West Virginia and Pennsylvania.

American Cyanamid Acquires Burton Explosives

American Cyanamid & Chemical Corporation announces the acquisition, effective July 1, 1934, of the plant, properties and business of Burton Explosives, Inc., Cleveland, O., which latter company has since its organization in 1930 been engaged in the manufacture and sale of high explosives and blasting supplies.

The explosives plant, covering 415 acres, is located at New Castle, Pa., with a capacity of 18,000,000 lb. annually. The plant is complete for the production of commercial high explosives and is designed to prepare and manufacture a number of the raw materials used. Plant and processes are the result of the long experience of Mr. Burton and his associates. The processes and methods installed result in an extremely economical operation.

The acquisition of this company brings to the American Cyanamid organization a large production of high explosives and an established distributing organization covering 20 states with magazines conveniently located to serve the trade in that area. "Burton Explosives" have been well and favorably known. Their high standards of quality and service will be maintained and expanded.

J. S. Burton, president of Burton Explosives, Inc., brings to American Cyanamid organization a thorough knowledge of the explosive business together with a manufacturing and sales organization of experienced men of proven ability in their respective fields. Mr. Burton has been connected with the industry since 1895.

The business of Burton Explosives, Inc., will be carried on as the Burton Explosives Division of the American Cyanamid & Chemical Corporation, 30 Rockefeller Plaza, New York, N. Y.